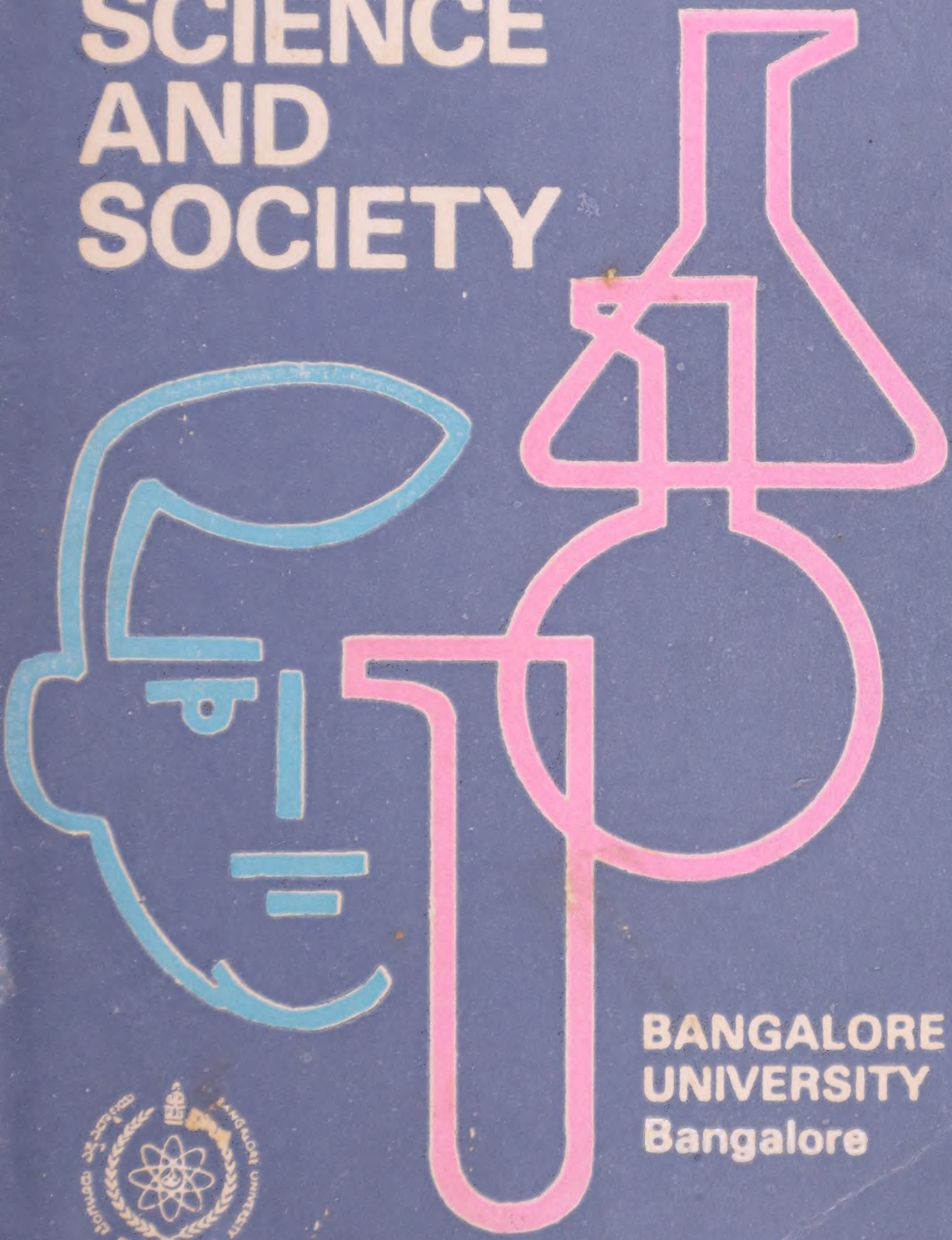
THOUGHTS ON SCIENCE AND SOCIETY



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Let noble thoughts
come to us from every side

Thoughts on Science and Society

BANGALORE UNIVERSITY
BANGALORE

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To The Graduates....

Stupendous progress is being made in the field of Science and Technology. The scientist is on the verge of creating life in the laboratory. Man has gone to the moon and returned successfully. It is a tribute to the inquiring, restless and undaunted spirit of man for having unravelled many a mystery of Nature. That which was considered supernatural yesterday is made perfectly natural to-day. This is one side of the picture.

The other side of the picture is very depressing. A scientist or a student of science will try to be highly rational in his approach to problems inside the laboratory. But it is shocking to find many a time the same 'rational' man being hopelessly irrational in trying to solve the problems of life. It seems as though his thinking faculty has taken a holiday.

Our country is supersaturated with superstitions. An educated superstitious person is more dangerous to the society than his uneducated counterpart. It is unfortunate that the attention and respect accorded to science is directed wholly to its results, and its spirit is most unpopular in this world. Yet it is reasonable to claim that it is in its spirit that the chief value of science resides.

I hope that this book which is presented to you on the occasion of the Eleventh Convocation, will remind you that education is a never-ending process stretching far behind this event.

With best wishes for a meaningful and useful life,

H. Narasimhaiah

Bangalore
December 7, 1975

Vice-Chancellor

Acknowledgement

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The Scientist: His responsibility and dignity

ALBERT EINSTEIN

We are living in a period of such great external and internal insecurity and with such a lack of firm objectives that the mere confession of our convictions may be of significance even if these convictions, as all value judgements, cannot be proven through logical deductions.

There arises at once the question : should we consider the search for truth—or, more modestly expressed, our efforts to understand the knowable universe through constructive logical thought—as an autonomous objective of our work ? Or should our search for truth be subordinated to some other objective, for example, to a 'practical' one ? This question cannot be decided on a logical basis. The decision, however, will have considerable influence upon our thinking and our moral judgement, provided that it is born out of deep and unshakable conviction. Let me then make a confession : for myself, the struggle to gain more insight and understanding is one of those independent objectives without which a

thinking individual would find it impossible to have a conscious, positive attitude towards life.

It is the very essence of our striving for understanding that on the one hand, it attempts to encompass the great and complex variety of man's experience, and that on the other, it looks for simplicity and economy in the basic assumptions. The belief that these two objectives can exist side by side is, in view of the primitive state of our scientific knowledge, a matter of faith. Without such faith I could not have a strong and unshakable conviction about the independent value of knowledge.

This, in a sense, religious attitude of a man engaged in scientific work has some influence upon his whole personality. For apart from the knowledge which is offered by accumulated experience and from the rules of logical thinking, there exists in principle for the man in science no authority whose decisions and statements could have in themselves a claim to 'Truth'. This leads to the paradoxical situation that a person who devotes all his strength to objective matters will develop, from a social point of view, into an extreme individualist who, at least in principle, has faith in nothing but his own judgement. It is quite possible to assert that intellectual individualism and the thirst for scientific knowledge emerged simultaneously in history and remained inseparable ever since.

Someone may suggest that the man of science as sketched in these sentences is no more than an abstraction which actually does not exist in this world, not unlike the *homo oeconomicus* of classical economics. However, it seems to me that science as we know it today could not have emerged and could not have remained alive if many

individuals, during many centuries, had not come very close to the ideal.

Of course, not everybody who has learned to use tools and methods which, directly or indirectly, appear to be 'scientific' is to me a man of science. I refer only to those individuals in whom the scientific mentality is truly alive.

What then, is the position of today's man of science as a member of society? He obviously is rather proud of the fact that the work of scientists has helped to change radically the economic life of men by almost completely eliminating muscular work. He is distressed by the fact that the results of his scientific work have created a threat to mankind since they have fallen into the hands of morally blind exponents of political power. He is conscious of the fact that technological methods, made possible by his work, have led to a concentration of economic and also of political power in the hands of small minorities which have come to dominate completely the lives of the masses of people, who appear more and more amorphous. But even worse: the concentration of economic and political power in the hands of a few has not only made the man of science dependent economically, it also threatens his independence from within; the shrewd methods of intellectual and psychic influences which it brings to bear will prevent the development of independent personalities.

Thus the man of science, as we can observe with our own eyes, suffers a tragic fate. Striving in great sincerity for clarity and inner independence, he himself, through his sheer superhuman efforts, has fashioned the tools which are being used to make him a slave and to destroy him also from within. He cannot escape being muzzled by

those who have political power in their hands. As a soldier he is forced to sacrifice his own life and to destroy the lives of others even when he is convinced of the absurdity of such sacrifices. He is fully aware of the fact that universal destruction is unavoidable since historical development has led to the concentration of all economic, political and military power in the hands of national States. He also realizes that mankind can only be saved if a super-national system, based on law, would be created to eliminate for all time the methods of brute force. However, the man of science has slipped so much that he accepts the slavery inflicted upon him by national States as his inevitable fate. He even degrades himself to such an extent that he helps obediently in the perfection of the means for the general destruction of mankind.

Is there really no escape for the man of science? Must he really tolerate and suffer all these indignities?

Is the time gone for ever when, aroused by his inner freedom and the independence of his thinking and his work, he had a chance of enlightening and enriching the lives of his fellow human beings? In placing his work too much on an intellectual basis, has he not forgotten about his responsibility and dignity? My answer is: while it is true that an inherently free and scrupulous person may be destroyed, such an individual can never be enslaved or used as a blind tool.

If the man of science of our day could find the time and the courage to think honestly and critically over his situation and the tasks before him and if he would act accordingly, the possibilities for a sensible and satisfactory solution of the present dangerous international situation would be considerably improved.

Religion and Science: Irreconcilable?

Does there truly exist an insuperable contradiction between religion and science? Can religion be superseded by science? The answers to these questions have, for centuries, given rise to considerable dispute and, indeed, bitter fighting. Yet, in my own mind there can be no doubt that in both cases a dispassionate consideration can only lead to a negative answer. What complicates the solution, however, is the fact that while most people readily agree on what is meant by "science," they are likely to differ on the meaning of "religion".

As to science, we may well define it for our purpose as "methodical thinking directed toward finding regulative connections between our sensual experiences." Science, in the immediate, produces knowledge and, indirectly, means of action. It leads to methodical action if definite goals are set up in advance. For the function of setting up goals and passing statements of value transcends its domain. While it is true that science, to the extent of its grasp of causative connections, may reach important conclusions as to the compatibility and incompatibility of goals and evaluations, the independent and fundamental definitions regarding goals and values remain beyond science's reach.

As regards religion, on the other hand, one is generally agreed that it deals with goals and evaluations and, in general, with the emotional foundation of human thinking and acting, as far as these are not predetermined by the inalterable hereditary disposition of the human species. Religion is concerned with man's attitude toward nature at large, with the establishing of ideals for the individual and communal life, and with mutual human relationship.

These ideals religion attempts to attain by exerting an educational influence on tradition and through the development and promulgation of certain easily accessible thoughts and narratives (epics and myths) which are apt to influence evaluation and action along the lines of the accepted ideals.

It is this mythical, or rather this symbolic, content of the religious traditions which is likely to come into conflict with science. This occurs whenever this religious stock of ideas contains dogmatically fixed statements on subjects which belong in the domain of science. Thus, it is of vital importance for the preservation of true religion that such conflicts be avoided when they arise from subjects which, in fact, are not really essential for the pursuance of the religious aims.

When we consider the various existing religions as to their essential substance, that is, divested of their myths, they do not seem to me to differ as basically from each other as the proponents of the "relativistic" or conventional theory wish us to believe. And this is by no means surprising. For the moral attitudes of a people that is supported by religion need always aim at preserving and promoting the sanity and vitality of the community and its individuals, since otherwise this community is bound to perish. A people that were to honour falsehood, defamation, fraud, and murder would be unable, indeed, to subsist for very long.

When confronted with a specific case, however, it is no easy task to determine clearly what is desirable and what should be eschewed, just as we find it difficult to decide what exactly it is that makes good painting or good music. It is something that may be felt intuitively more

easily than rationally comprehended. Likewise, the great moral teachers of humanity were, in a way, artistic geniuses in the art of living. In addition to the most elementary precepts directly motivated by the preservation of life and the sparing of unnecessary suffering, there are others to which, although they are apparently not quite commensurable to the basic precepts, we nevertheless attach considerable importance. Should truth, for instance, be sought unconditionally even where its attainment and its accessibility to all would entail heavy sacrifices in toil and happiness? There are many such questions which, from a rational vantage point, cannot easily be answered or cannot be answered at all. Yet, I do not think that the so-called "relativistic" viewpoint is correct, not even when dealing with the more subtle moral decisions.

When considering the actual living conditions of present-day civilised humanity from the standpoint of even the most elementary religious commands, one is bound to experience a feeling of deep and painful disappointment at what one sees. For while religion prescribes brotherly love in the relations among the individuals and groups, the actual spectacle more resembles a battlefield than an orchestra. Everywhere, in economic as well as in political life, the guiding principle is one o ruthless striving for success at the expense of one's fellowmen. This competitive spirit prevails even in school and, destroying all feelings of human fraternity and cooperation, conceives of achievement not as derived from the love for productive and thoughtful work but as springing from persona ambition and fear of rejection.

There are pessimists who hold that such a state of affairs is necessarily inherent in human nature; it is

those who propound such view that are the enemies of true religion, for they imply thereby that religious teachings are utopian ideals and unsuited to afford guidance in human affairs. The study of the social patterns in certain so-called primitive cultures, however, seems to have made it sufficiently evident that such a defeatist view is wholly unwarranted. Whoever is concerned with this problem, a crucial one in the study of religion as such, is advised to read the description of the Pueblo Indians in Ruth Benedict's book, *Patterns of Culture*. Under the hardest living conditions, this tribe has apparently accomplished the difficult task of delivering its people from the scourge of competitive spirit and of fostering in it a temperate, cooperative conduct of life, free of external pressure and without any curtailment of happiness.

The interpretation of religion, as here advanced, implies a dependence of science on the religious attitude, a relation which, in our predominantly materialistic age, is only too easily overlooked. While it is true that scientific results are entirely independent from religious or moral considerations, those individuals to whom we owe the great creative achievements of science were all of them imbued with the truly religious conviction that this universe of ours is something perfect and susceptible to the rational striving for knowledge. If this conviction had not been a strongly emotional one and if those searching for knowledge had not been inspired by Spinoza's *Amor Dei Intellectualis*, they would hardly have been capable of that untiring devotion which alone enables man to attain his greatest achievements.

The Laws of Science and the Laws of Ethics

Science searches for relations which are thought to exist independently of the searching individual. This

includes the case where man himself is the subject. Or the subject of scientific statements may be concepts created by ourselves, as in mathematics. Such concepts are not necessarily supposed to correspond to any objects in the outside world. However, all scientific statements and laws have one characteristic in common: they are "true or false" (adequate or inadequate). Roughly speaking, our reaction to them is "yes" or "no".

The scientific way of thinking has a further characteristic. The concepts which it uses to build up its coherent systems are not expressing emotions. For the scientist, there is only "being" but no wishing, no valuing, no good, no evil; no goal. As long as we remain within the realm of science proper, we can never meet with a sentence of the type: "Thou shalt not lie." There is something like a Puritan's restraint in the scientists who seeks truth: he keeps away from everything voluntaristic or emotional. Incidentally, this trait is the result of a slow development, peculiar to modern Western thought.

From this it might seem as if logical thinking were irrelevant for ethics. Scientific statement of facts and relations, indeed, cannot produce ethical directives. However, ethical directives can be made rational and coherent by logical thinking and empirical knowledge. If we can agree on some fundamental ethical propositions, then other ethical propositions can be derived from them, provided that the original premises are stated with sufficient precision. Such ethical premises play a similar role in ethics, to that played by axioms in mathematics.

This is why we do not feel at all that it is meaningless to ask such questions as: "Why should we not lie?" We feel that such questions are meaningful because in all

discussions of this kind some ethical premises are tacitly taken for granted. We then feel satisfied when we succeed in tracing back the ethical directive in question to these basic premises. In the case of lying this might perhaps be done in some way such as this : Lying destroys confidence in the statements of other people. Without such confidence, social cooperation is made impossible or at least difficult. Such cooperation, however, is essential to make human life possible and tolerable. This means that the rule "Thou shalt not lie" has been traced back in the demands: "Human life shall be preserved" and "Pain and sorrow shall be lessened as much as possible."

But what is the origin of such ethical axioms ? Are they arbitrary ? Are they based on mere authority ? Do they stem from experiences of man and are they conditioned indirectly by such experiences ?

For pure logic all axioms are arbitrary, including the axioms of ethics. But they are by no means arbitrary from a psychological and genetic point of view: They are derived from our inborn tendencies to avoid pain and annihilation, and from the accumulated emotional reaction of individuals to the behaviour of their neighbours.

It is the privilege of man's genius, impersonated by inspired individuals, to advance ethical axioms which are so comprehensive and so well founded that men will accept them as grounded in the vast mass of their individual emotional experiences. Ethical axioms are found and tested not very differently from the axioms of science. Truth is what stands the test of experience.

Ethics in the Relationship between Science and Society

Interview with EUGENE P. WIGNER

The man or woman choosing the profession of scientific research is not a superperson, endowed with rights and privileges surpassing those of ordinary mortals. The researcher has obligations, even the need, to interact with the rest of society. He is blessed by the pleasure that scientific method and revelation can bring. He should try to share this pleasure with his fellow-men.

How do you evaluate your research work as a contribution to society as a whole?

Most of my work has been in pure science. Its influence on society, if it should have any, will come in the distant future. I did contribute to the development of nuclear energy; I not only hope, but I am convinced, that the use of this energy will be beneficial to mankind for many years to come.

I may have contributed less to society by my scientific work than by my insistence on clear thinking on the part of scientists on political questions and by having tried to contradict emotionally motivated inaccuracies.

If you were to begin again, would you become a scientist ? If so, doing what ?

I might become an anthropologist. At least, that is my inclination. Among my friends, however, those who know me best are quite doubtful. They believe that I would again become a physicist, concerned about the mathematical formulation of that discipline.

How do you think that research in physics contributes to human well-being ?

The contribution of physics to the human condition is diminishing, since it is now materially possible for people to have a life reasonably free of worry about what they will eat tomorrow. I believe that physics has accomplished its part, so to speak, as far as man's material welfare is concerned. I think that mankind's major problems now are of a social and emotional nature. For this reason, the gifts of the beauty and grandeur of science to man's emotional make-up may become the important new contributions to his well-being.

What are the political and social responsibilities of scientists ?

I oppose the notion that scientists form a privileged caste. Their social and political obligations are the same as those of other citizens. Only when they are better informed on some question that most of their fellow citizens do they have the *special* obligation, and the privilege, to convey information to their fellow-men. It is also incumbent

upon them not to misinform or to present information of doubtful validity as firmly established fact.

The scientific community has frequently been criticised because some of its members have offered the public data or conclusions strongly coloured by the political orientation or value judgement of the individual scientist. This undermines the public faith in our statements and, therefore, much of the usefulness of the information we *can* provide.

Simply because we have helped to invent the automobile gives us no more right to decide about its use than has the mechanic who participated in the production of the car. Just as he is compensated by wages and a sense of accomplishment, so we scientists are compensated by our salaries and the pleasure of our work. Neither of us has an absolute *right* to the product.

How do you suppose the relationship between scientists and society will evolve in the future?

This is a most difficult question. I can and do hope, though, that we men and women of science will not shed our modesty, that we will not want to dictate what other people should want or to determine in what they should find pleasure. We could try, and should, to increase the level of human happiness by interesting more people in science, by inducing them to experience the pleasure which our own occupation with science gives us.

Do you believe that greater support should be given to research in the social sciences, perhaps even at the expense of the natural sciences?

It is quite possible that we physicists are biased when comparing the promises of the social and natural sciences.

At any rate, I believe that, with the exception of economics, the social sciences are not yet ready to benefit from the methodology of 'big science'. That is to say, significant material support of the social sciences would advance them little. Indeed, such support could have an adverse effect by impelling social scientists to produce results fast, and in large volume.

What social science needs is quiet devotion and intensive contemplation (such as practised by Freud, for instance), and not large organisations, elaborately contrived. Devotion and contemplation are not fostered by extensive material aid. Our social problems are certainly more pressing than questions of high-energy physics, but progress in the social sciences (except economics, I repeat) is less dependent on money than on dedication, enthusiasm, and the individual's determination to contribute.

In the long term, which contributes most to society : basic research or mission-oriented research ?

This is a difficult question, too, because it is so hard to define contributions 'in the long term'. If we take indirect contributions into account, the discovery of differential calculus has contributed ultimately more to man's welfare than any mission-oriented research. If, however, we consider only direct and immediate effects, it is true that those resulting from mission-oriented big science are far greater than those of spontaneous, fundamental research.

Most mission-orientation imposed from the outside is directed toward a goal which can–and should–be attained. But some mission-oriented work is the result of individual motivation, the conviction of the scientist that he can

solve a certain problem. As in individual research, this involves the element of luck.

Do you think that research should be closely managed in order to permit it to concentrate on society's needs ?

One of the most profound thinkers (and incisive writers) on the problems of science and its obligations toward society is Alvin M. Weinberg. It is he who created the abstraction of the big science I have referred to and of 'little science'. Little science was begun and advanced either by solitary workers or small, tightly knit groups, either as a companion effort to teaching or other occupations (such as patent office work, as in the case of Einstein). Only a small number of scientists had no other obligation but to create science, and they worked alone, with little material support from society.

This is what science was before the 1940s and is what little science is now. Even today, most of our scientific knowledge remains the contribution of little science. Since the latter has given so immeasurably to human welfare, its cultivators have almost invariably chosen their field of interest without pressure from the outside. They should be permitted to continue to do so.

Big science, on the other hand, was started because some problems of a scientific or technical nature did not seem to be amenable to solution except by large concentrations of mixed disciplines, well organised, using expensive equipment, and relying considerably on material assistance from the rest of society. It was natural for society to demand its share of influence on the choice of big science's objectives. It seems to me only fair that, at least, some of big science should be responsive to the needs of that society.

Are you satisfied that scientific research has done its share to help advance the well-being of us human beings ?

Let me repeat something I said on another occasion. Although the effect of science and civilisation on human happiness cannot be measured with precision, it is surely present. Given the current state of our understanding of human emotions, we cannot even say with certainty whether an educated person or a simple child of nature is, on the average, happier. Given the freedom from want now prevailing at least in the advanced nations of the world, I think many people would agree with me (paradoxically, perhaps) that there may be one exception to what I have just said.

This is what I mean : we, scientists, do derive much pleasure and satisfaction from our work, and this contributes a great deal to our happiness. I truly believe that we men and women of science should help others to enjoy some of the fruits of our work, to participate in the pleasure that we derive from our daily efforts in science.

Until philosophers are kings, or the kings and princes of this world have the spirit and power of science, and political greatness and wisdom met in one, neither states nor the human race itself will ever have the rest from their evils.

Plato

Science and Humanism

ERWIN SCHRODINGER

The spiritual bearing of science on life

What is the value of scientific research? Everybody knows that in our days more than ever before a man or a woman who wishes to make a genuine contribution to the advancement of science has to specialise, which means to intensify one's endeavour to learn all that is known within a certain narrow domain and then to try and increase this knowledge by one's own work—by studies, experiments, and thinking. Being engaged in such specialised activity one naturally at times stops to think what it is good for. Has the promotion of knowledge within a narrow domain any value in itself? Has the sum total of achievements in all the several branches of *one* science – say of physics, or chemistry, or botany, or zoology – an value in itself – or perhaps the sum total of the achievements of all the sciences together – and *what* value has it?

A great many people, particularly those not deeply interested in science, are inclined to answer this question by pointing to the practical consequences of scientific

achievements in transforming technology, industry, engineering, etc., in fact in changing our whole way of life beyond recognition in the course of less than two centuries, with further and even more rapid changes to be expected in the time to come.

Few scientists will agree with this utilitarian appraisal of their endeavour. Questions of values are, of course, the most delicate ones; it is hardly possible to offer incontrovertible arguments. But let me give you the three principal ones by which I should try to oppose this opinion.

Firstly, I consider natural science to be very much on the same line as the other kinds of learning - or *Wissenschaft,* to use the German expression – cultivated at our universities and other centres for the advancement of knowledge. Consider the study or research in history or languages, philosophy, geography – or history of music, painting, sculpture, architecture–or in archaeology and pre-history; nobody would like to associate with these acctivities, as their principal aim, the practical improvement of the conditions of human society, although improvement does result from them quite frequently. I cannot see that science has, in this respect, a different standing.

On the other hand (and this is my second argument), there are natural sciences which have obviously no practical bearing at all on the life of the human society: astrophysics, cosmology, and some branches of geophysics. Take, for instance, seismology. We know enough about earthquakes to know that there is very little chance of foretelling them, in the way of warning people to leave their houses, as we warn trawlers to return when a storm

is drawing near. All that seismology could do is to warn prospective settlers of certain danger zones; but those, I am afraid, are mostly known by sad experience without the aid of science, yet they are often densely populated, the need for fertile soil being more pressing.

Thirdly, I consider it extremely doubtful whether the happiness of the human race has been enhanced by the technical and industrial developments that followed in the wake of rapidly progressing natural science. I cannot here enter into details, and I will not speak of the future development–the surface of the earth getting infected with artificial radio-activity, with the gruesome consequences for our race, depicted by Aldous Huxley in his horribly interesting recent novel *(Ape and Essence)*. But consider only the "marvellous reduction of size" of the world by the fantastic modern means of traffic. All distances have been reduced to almost nothing, whenmeasured not in miles but in hours of *quickest* transport. But when measured in the costs of even the *cheapest* transport they have been doubled or trebled even in the last 10 or 20 years. The result is that many families and groups of close friends have been scattered over the globe as never before. In many cases they are not rich enough ever to meet again, in others they do so under terrible sacrifices for a short time ending in a heart-rending farewell. Does that make for human happiness? These are a few striking examples; one could enlarge on the topic for hours.

But let us turn to less gloomy aspects of human activities. You may ask – you are bound to ask me now: What, then, is in your opinion the value of natural science? I answer: its scope, aim and value is the same as that of any other branch of human knowledge. Nay, none of them alone, only the union of all of them, has

any scope or value at all, and that is simply enough described: it is to obey the command of the Delphic deity, "get to know yourself". Or, to put it in the brief, impressive rhetoric of Plotinus (*Enn.* VI, 4, 14): "And we, who are we anyhow?" He continues: 'Perhaps we were there already before this creation came into existence, human beings of another type, or even some sort of gods, pure souls and mind united with the whole universe, parts of the intelligible world, not separated and cut off, but at one with the whole'.

I am born into an environment — I know not whence I came nor whither I go nor who I am. This is my situation as yours, every single one of you. The fact that everyone always was in this same situation, and always will be, tells me nothing. Our burning question as to the whence and whither — all we can ourselves observe about it is the present environment. That is why we are eager to find out about at as much as we can. That is science, learning, knowledge, that is the true source of every spiritual endeavour of man. We try to find out as much as we can about the spatial and temporal surrounding of the place in which we find ourselves put by birth. And as we try, we delight in it, we find it extremely interesting. (May *that* not be the end for which we are there?)

It seems plain and self-evident, yet it needs to be said: the isolated knowledge obtained by a group of specialists in a narrow field has in itself no value whatsoever, but only in its synthesis with all the rest of knowledge and only in as much as it really contributes in this synthesis something toward answering the demand: "who are we?"

Jose Ortega Y Gasset, the great Spanish philosopher, who is now after many years of exile back in Madrid

(though he is, I believe, just as little a fascist as a *sozialdemokrat*, but just an ordinary reasonable person), published in the twenties of this century a series of articles which were later collected in a delightful volume under the title of *La rebelion de las masas* – the rebellion of the masses. It has, by the way, nothing to do with social or other revolutions, the *rebelion* is meant purely metaphorically. The Age of Machinery has resulted in sending the numbers of the populations and the volume of their needs up to enormous heights, unprecedented and unforeseeable. The daily life of every one of us becomes more and more entangled with the necessity of coping with these numbers. Whatever we need or desire a loaf of bread or a pound of butter, a bus-lift or a theatre-ticket, a quiet holiday resort or the permit to travel abroad, a room to live in or a job to live on.. there are always many, many others having the same need or desire. The new situations and developments that have turned up as the result of this unparalleled soaring of the numbers from the subject of Ortega's book.

It contains extremely interesting observations. Just to give you an example–though it does not concern us at the moment–one chapter-heading reads *El major peligro, el estado :* the greatest danger – the state. He there declares the increasing power of the state in the curtailing individual freedom – under the pretext of protecting us, but far beyond necessity – to be the greatest danger to the future development of culture *(Kultur)*. But the chapter I wish to speak of here is the preceding one; it is entitled *La barbarie del 'especialismo'* the barbarism of specialisation. At first sight it seems paradoxical and it may shock you. He makes bold to picture the specialised scientist as the typical representative of the brute ignorant rabble - the

hombre masa (mass–man)–who endanger the survival of true civilisation. I can only pick out a few passages from the delightful description he gives of this 'type of scientist without precedent in history'.

> He is a person who, of all the things that a truly educated person ought to know of, is familiar only with one particular science, nay even of this science only that small portion is known to him in which he himself is engaged in research. He reaches the point where he proclaims it a virtue not to take any notice of all that remains outside the narrow domain he himself cultivates, and denounces as *dilettantist* the curiosity that aims at the synthesis of all knowledge.
>
> It comes to pass that he, secluded in the narrowness of his field of vision, actually succeeds in discovering new facts and in promoting his science (which he hardly knows) and promoting along with it the integrated human thought – which he with full determination ignores. How has anything like this been possible, and how does it continue to be possible? For we must strongly underline the inordinateness of this undeniable fact: experimental science has been advanced to a considera ble extent by the work of fabulously mediocre and even less than mediocre persons.

I shall not continue the quotation, but I strongly recommend you to get hold of the book and continue for yourself. In the twenty-odd years that have passed since the first publication, I have noticed very promising traces of opposition to the deplorable state of affairs denounced by Ortega. Not that we can avoid specialisation altogether; that is impossible if we want to get on. Yet the awareness that specialisation is not a virtue but an unavoidable evil is gaining ground, the awareness that all specialised research has real value only in the context of the integrated totality of knowledge. The voices become fainter and fainter that accuse a man of dilettantism who dares to think and speak and write on topics that require more than the special training for

which he is "licensed" or "qualified". And any loud barking at such attempts comes from very special quarters of two types — either very scientific or very unscientific quarters — and the reasons for the barking are in both cases translucent.

In an article on "The German Universities" (published on 11 December 1949 in *the Observer*) Robert Birley, Headmaster of Eton, quoted some lines from the report of the Commission for University Reform in Germany — quoted them very emphatically, an emphasis that I fully endorse. The following is said in this report:

> Each lecturer in a Technical University should possess the following abilities:
>
> a) To see the limits of the subject matter. In his teaching to make the students aware of these limits, and to show them that beyond these limits forces come into play which are no longer entirely rational, but arise out of life and human society itself.
>
> b) To show in every subject the way that leads beyond its own narrow confines to broader horizons of its own, etc.,

I won't say that these formulations are peculiarly original, but who would expect originality of a committee or commission or board or that sort of thing? – mankind *en masse* is always very commonplace. Yet one is glad and thankful to find this sort of attitude prevailing. The only criticism if it be criticism — is that one can see no earthly reason why these demands should be restricted to the teachers at *technical* universities in *Germany*. I believe they apply to *any* teacher at *any* university, nay, at any school in the world; I should formulate the demand thus:

Never lose sight of the role your particular subject has within the great performance of the tragi-comedy of

human life; keep in touch with life – not so much with practical life as with the ideal a background of life, which is ever so much more important; and *keep life in touch with you.* If you cannot – in the long run – tell everyone what you have been doing, your doing has been worthless.

The Practical Achievements of Science tending to obliterate its True Import

Scientific education is fabulously neglected, not only in this or that country-though, indeed in some more than in others. This is an evil that is inherited, passed on from generation to generation. The majority of educated persons are not interested in science, and are not aware that scientific knowledge forms part of the idealistic background of human life. Many believe – in their complete ignorance of what science really is – that it has mainly the ancillary task of inventing new machinery, or helping to invent it, for improving our conditions of life. They are prepared to leave this task to the specialists, as they leave the repairing of their pipes to the plumber. If persons with this outlook decide upon the curriculum of our children, the result is necessarily such as I have just described it.

There are, of course, historical reasons why this attitude still prevails. The bearing of science on the idealistic background of life has always been great-apart perhaps from the Dark Ages, when, science practically did not exist in Europe. But it must be confessed that there has been a lull also in more recent times, which could easily deceive one into under-rating the idealistic task of science. I place the lull about in the second half

of the nineteenth century. This was a period of enormous explosion–like development of science, and along with it of a fabulous, explosion–like development of industry and engineering which had such a tremendous influence on the material features of human life that most people forgot any other connections. Nay, worse than that: The fabulous *material* development led to a *materialistic* outlook allegedly derived from the new scientific discoveries. These occurrences have, I think, contributed to the deliberate neglect of science in many quarters during the half century that followed–the one that is just drawing to a close. For there always is a certain time-lag beween the views held by learned men and the views held by the general public about the views of those learned men. I do not think that fifty years is an excessive estimate for the average length of that time-lag.

Be that as it may, the fifty years that have just gone by – the first half of the twentieth century – have seen a development of science in general, and of physics in particular, unsurpassed in transforming our Western outlook on what has often been called the Human Situation. I have little doubt that it will take another fifty years or so before the educated section of the general public will have become aware of this change. Of course, I am not so much an idealistic dreamer as to hope substantially to accelerate this process by a couple of public lectures. But, on the other hand, this process of *assimilation* is not automatic. *We have to labour for it.* In this labour I take my share, trusting that others will take theirs. It is part of our task in life.

Science, Culture and Government

GLENN T. SEABORG

The underlying quality of life for which we strive in a democratic society not only involves total economic and social change but full consideration of the well-being of the individual in the society. Maintaining a maximum of freedom and opportunity for growth for the individual in a world of overwhelming technological forces and growing social interdependence and responsibility is a major challenge of our times. And it is a challenge which many feel cannot be met fully without a more meaningful interplay between the sciences, the humanities and arts, education and government; forces which up to now have acted to a great degree separately, and sometimes at odds with each other.

The scientific revolution and the overlooked individual

It was not until after the Second World War that large-scale government involvement in science evolved. It was during this era when the chemical industry accelerated its rapid growth based on new discovery and innovation, and when in physics, as Robert Oppenheimer

characterized it, we shook the tree of earlier theoretical science and applied the knowledge gathered to help develop new and potent technologies to help the country foster the scientific revolution.

This scientific revolution, since the birth of the Atomic Age, has led many people to discover science : that is, to realise its power to produce substantial material gains when its methods and knowledge are put to use by modern technology.

What has been most notable about that scientific Revolution – and probably what characterises it as a revolution – has been the increasing speed with which theoretical discovery has found its way to practical application. And today, as the time gap between discovery and application continues to narrow, so does the social impact of science grow with an almost exponential force.

As opposed to our technological know how, how have we developed 'value-wise', 'culture-wise', or even 'wise-wise' ?

I feel we have been developing an imbalance in our national personality, one which arises from a well-intentioned emphasis on technological gain but one which weakens our framework of values nevertheless. Our concern with efficiency and economy, with power and production-with our over'all desire to do the job'-dominates our reasons for doing the job. In our preoccupation with 'means' we have lost sight of many of the 'ends'. We set more production goals but fewer human goals. We think more of developing 'systems' and less of developing individuals. We chart the course of our businesses and our economy but not the measure of our success or failure in providing human fulfilment. Granted there is no

equivalent to the GNP to measure the fulfilment of human values, we seem to give the former far more thought and concern than the latter.

Today our concern with the techniques for achieving many of these goals has somehow pushed the individual into the background. At times he feels sorely neglected as a human being.

Yet most of this behaviour has some constructive meaning. Most importantly, it calls the country's attention to needs which are being overshadowed in today's technological society, the basic needs of a person to have an individual identity, a sense of purpose and accomplishment in his life, and outlets for his physical and creative energy.

In today's restlessness and rebellion, we are being made aware of change and of the need for action to deal with it. And I believe the nation can deal effectively with its social and psychological needs, as well as its technological and economic ones. I believe it can deal with them by emphasizing in its plans and work the human values which in recent times have been overshadowed, overlooked or inadvertently bulldozed aside by momentum of a benign but often bumbling technology.

In the light of on-going events I think we have begun this re-emphasis on man's role in the scientific age. I feel that perhaps we are now at a time in our history where, breathless from a headlong pursuit of material gains, we have paused to look around and reflect, and this has engendered in us a new awareness of the total condition of our lives and a broader outlook of the future. During our reflection we have arrived at some badly needed insight into significant needs.

Today, with our new awareness of change and our realisation that we can and must be the masters of that change,we are also taking a more positive attitude towards emphasising and cultivating human and aesthetic values.

There has been the attitude that government support of any educational or creative process would lead to its control by that government. Many have used as an example of this sort of culture-control the book-burning tyranny of Nazi Germany, or the directing of the arts toward propaganda, as is done in some countries. But I think that what transpires in this relationship between support and control depends on the basic philosophy of the nation.

Uniting the 'two' cultures

Though science may have a pervading and ascending influence in our lives today, there cannot be any clear-cut division between science and non-science in the interdisciplinary civilisation which a livable future world will require. The growing overlapping of the 'two cultures' becomes obvious to those who care to pause and look for it.

Some people, apprehensive over the rate and degree of change brought about by the applications of science talk of science as if it were a force apart from man. What they tend to overlook is the simple fact that science is after all a human endeavour and that it does not exist independent of man. We must not forget that in over all history science has, so far, done more to 'humanise' than to 'dehumanise' man.

Perhaps, also, a society which fosters this combination of wisdom and knowledge, and which tries to keep

its focus on individual human values within an ever-growing nation, will be able to develop some immunity to the 'anti-leadership vaccine' which is described as one of today's new problems in education.

University Freedom

As the government-university partnership grows and expands into the arts and humanities, increasing responsibility is thrust upon both parties to insure university freedom. For its part, the government must exercise great restraint in the imposition of conditions and regulations. The university can encourage such restraint and maintain its independence in a number of ways. Foremost among measures that insure maximum university independence is the maintenance of excellence in government-supported programmes.

Obviously large-scale dependence of universities on Government funds has its hazards. Yet I believe that the government–university partnership can be managed so as not to be subversive of university freedoms. But let me emphasise this : the greatest responsibility for keeping our universities free and self-reliant rests with the universities themselves. They must see to it that their own standards of excellence and freedom are maintained in a period of growing relationship with government. From my own knowledge of government I feel strongly that this is possible if the universities adopt and maintain a courageous, firm, vigilant, reasonable and just attitude towards this partnership.

The universities—with government help—have an enormous challenge ahead of them in performing their primary functions : to expand knowledge and to equip

our best young people for creative work in a wide variety of disciplines.

As I see it, the universities' task is to approach, with intellectual honesty and moral courage, the deep–rooted problems that lie at the base of today's ferment. There is validity in much that troubles thoughtful young people today. They see a world of immense potentials for material productivity inhibited by inertia in patterns of distribution, of affluence existing adjacent to poverty, of abuse of our environment, of knowledge and concern amid ignorance and indifference, of political turmoil and philosophical upheaval.

One must sympathise with the idealism of the young and with their concerned desire to influence change. And the defence against destructive apocalyptic solutions is to effect demonstrable change where it is called for and to show the young that they can influence the course of events through participation in our institutional processes.

I believe the universities can occupy an increasingly central role in the community in forthcoming years. To some extent they have been serving the needs of an industrial society which has been only partly and indirectly of their making. In the future I see the possibility of our universities substantially shaping the goals of society. Not that the world will be ruled by a handful of professors. Rather, I believe, society will find merit in the ideas and values generated in the universities.

Thus, universities will shape the educational experience from the earliest years through the full lifetime, a broad experience equipping the individual for maximum intellectual achievement and a capacity to live with man, machines, leisure and change. As Robert Theobald

suggests, education in the age of the Cybernetic Revolution will not be directed toward 'earning a living' but toward 'total living'.

Shaping the Future through Science

We face some very negative opinions today about science and technology in particular, about man in general, and about their relationships. Broadly speaking, we are told that man is a failure and that science and technology are responsible. This attitude is expressed in many ways by many groups and individuals. There are the bands of disenchanted youths who go off to reject modern society by living in countryside communes where they move closer to nature but still need electricity, still drive to town to pick up supplies with which to live, and still depend on the benefits of that society's laws, communications and public health and medical knowledge. There are those groups who, not having gone so far as rejecting all of society, reject all of science and technology on the grounds that some of it serves military, social or political causes with which they do not agree. Yet many of these are the very same groups that clamour for the uplifting of the people of under-developed lands, admitting that science and technology must play a role in their advances.

And there are those groups and individuals who are just as unilateral in their critiques of science and technology from other standpoints–some claiming they are leading us towards irreversible ecological destruction, others saying they are the source of an alienation that deprives us of our humanity, and still others seeing them as forces separating us from a biological inheritance that we should retain. Yet all of these will agree, after some reflection,

that science and technology have contributed to our humanity, are needed to deal constructively with ecological problems and could be directed to establish a healthy relationship between man and his environment.

There is a strange mixture of tragedy and truth in all these outlooks – and, unfortunately, a strange distortion of past history and present reality also. The young hippie, for example – the new Thoreau – who goes off with his companions to live a communal life close to nature, on matter how noble his intentions or how strong his feelings, cannot be a model for his fellowman. In his total dedication to his values he can only become a parasite, reflecting a kind of pseudo-independence from the modern world. And should this aspect of his life-style be emulated by all his fellow youth, social and ecological disaster would eventually follow. Contrary to many romantic notions that abound today, nature alone could not support the billions of people on earth now (and the billions due even with population control). Should this be even partially attempted, every hardship that man has suffered in the past would be visited upon him manyfold, nature and man would be devastated in constant conflict with each other, and we would see eventually, rather than the communal spirit and love projected by the young idealists, an aggressiveness and vicious competitiveness the like of which history never revealed. If you do not believe me, try projecting what the world would be like as each of the benefits of modern science and technology were removed and then all the people of the world were asked to retreat further and further into those supposedly ideal and idyllic yesteryears when men lived closer to nature.

But I dislike even suggesting such an exercise because there is a basic flaw in the 'return to nature' idea – to the

idea that anything that man does scientifically or technologically is somehow 'unnatural'. This is a powerful notion, a pervasive feeling, that runs through the thinking of so many people today as a reaction to some of the problems which science and technology have created. And while there is no doubt that we have an inherent love of the natural and a need to enjoy nature's attributes, that love and that enjoyment are enhanced and highlighted today because we have the luxury of enjoying nature as a friend and not a foe. The people of the U. S. who can drive to a campsite in a National Park and set up housekeeping in a camper or tent trailer with all the conveniences of home, can afford to think and feel differently about nature than those people of East Pakistan for example, some of whom, as seen in the last holocaust there, have little choice but to live or die according to nature's whims.

My main point, however, is not based merely on this comparison of perspectives. It is based on the idea that modern man is neither acting 'unnatural' nor separating himself from nature. He is, in the broadest sense 'doing what comes naturally.' For if we reflect even for a moment we can realise how much science and technology are a part of nature's evolutionary process. How can this be so? The answer is not difficult to follow. Nature has endowed all forms of life with some protective or responsivemeans of survival. But what has she given man in his evolution? He is most poorly equipped in many ways. His vision is terrible compared with a bird's. His sense of smell is inferior to almost every four-legged animal. His natural means of locomotion are relatively clumsy. He benefits from no camouflage, no claws, no large incisors, and in his birthday suit he is ill-equipped to live in most of the world's climate.

What, then, did nature give man? She developed in him a brain and neural system, and a degree of manual dexterity, that allows him to amplify his limited powers through abstract thought, language and the use of tools and energy. His survival and evolution are based on a dynamic interplay of these, and on his ability to grow by his adjustment to the feedback from his errors and successes. And I contend that his evolution today, through the various civilisations and societies we have seen, and into the modern global one that is struggling to be born, is a *natural* evolutionary process. Furthermore, it is a process that is moving us, not toward self-destruction, but toward a higher form of life. It is forcing moral and social growth and preparing man for what John Platt has referred to recently as a 'Hierarchical Jump' to a new level of man or mankind.

So let me reemphasize that, contray to much that is heard today, science and technology are not unnatural or anti-nature, nor are they aberrations of human development that will lead to man's downfall. Anyone who merely compiles their errors and their human misuses in a one-sided picture to condemn and dismiss them as that, is totally lacking in vision. If man were to pursue the illusion that he could 'adjust' to nature without a constant upgrading of his science and technology he would soon be extinct. Those who would depend for survival strictly on nature's ecological balance, devoid of man's intellectual equalisers, would witness the rapid decline of man and the ascendancy of another species–most likely the insect, perhaps even the lowly cockroach who, we are told, has survived for millions of years and is still going strong.

But in stating my case in defending science and technology from this broad standpoint, I decidedly do

not want to give the impression that I believe science and technology as used by human beings are unmitigated good, that all the criticism of them today is invalid or undeserved, or that much good may not result from the values of our youth's 'counter-culture' on our 'science culture.' Feedback from such a 'counter-culture' is absorbed and the best of it will have a good and lasting effect on our society. It simply is not true that our scientific-technological civilisation is unresponsive to, or destructive of, our humanity. In total, it is a very human and humane enterprise that is guided by human drives and that tends to elevate, not debase, those drives.

It seems to me that, among other things, civilisation progresses through our use of a combination of hindsight, insight and foresight–with our advances depending largely on the extent to which we can emphasise the latter two. A review of all the popular material on environmental and social problems today shows that at the moment we are still very heavy on hindsight, although there is much good insight coming through now. The result is that we are still spending too much time and effort in seeking out scapegoats for today's ills and making historical comparisons which are unproductive and invalid.

In this same vein we have many people who see the past and present through a strange pair of glasses, one that filters out our human advances as they approach the present and highlights only the 'glories of the past', giving the impression that the total condition of man is regressing. Nothing could be further from the truth – all our environmental problems notwithstanding.

If we want to shape the future – and particularly through science and technology – we must get out of the

traps created by the despair of today's cynics or the frustration generated by unrealistic expectations. Neither condition allows us to develop the proper insight and move on to applying the necessary foresight which is so important today.

How then shall we move ahead? What should we expect from science and technology? What needs to be done to use them to the best advantage? And if this is done where might they take us? In other words, what will be the shape of the future they provide?

To answer these questions we must explore a basic dilemma of our times. That dilemma, stated oversimply is: How can we have the growth to meet expectations already generated – global expectations that seem to make virtually unlimited demands – in a world of physical limitations, many of which are already being approached? The immediate reaction to this (and it is one shared by many people today) is to stop the growth; or to be more explicit, limit population, reduce expectations, lower production and pollution and concentrate on the redistribution of material things and the 'quality of life.' This is a very natural, rational and human reaction. But, unfortunately, taken as a single prescription, it is neither a very realistic nor imaginative one.

When contrasted with the major feelings of only a few short years ago that the 'sky was the limit', that economic growth was synonymous with progress and that both were essentially limitless, the new attitude seems far more sane. And I agree that if it were simply an either/or proposition I would immediately side with those who opt for the freeze. For the natural limitations, physical and otherwise, of uncontrolled growth are obvious.

And rather than blindly moving ahead into their devastating effects, rather than letting natural laws put a harsh stop to our growth, we would be better off imposing our own limits, harsh as they also might seem to some.

But we are *not* faced with a strictly either/or proposition. Economic growth and ecological balance are not necessarily incompatible. There are areas where new growth and development are essential and there are those in which they should be levelled off or even cut back. There is also a new morality being introduced into the marketplace that will allow economic values to be assigned to environmental necessities so that through a combination of regulations and incentives we can enjoy a type of human advancement neither tied only to a rising GNP nor bound to a harsh zero-growth policy. The key to this middle way, however, lies mainly in the wise development and application of science and technology.

To the hungry and the poverty-stricken ecology is irrelevant. Not having Social Security, or much other security, they breed for survival – to assure the perpetuation of their people and to have the necessary support should they survive to old age. So that while important programmes of population control have been moderately successful they struggle against a natural instinct that could be adjusted by greater development, development that can take place through advances of science and technology without further environmental degradation and within some kind of rational economic framework.

Of courses the ability to lift a people above a marginal existence to a position where they have the strength and will to further advance must be supplemented by other

means of development. Energy, education, improved transportation and communication systems, and appropriate industry must be brought in. But not in the way they were introduced into today's advanced nations, for then they would repeat and compound many-fold the environmental and social problems those nations face. And here is where advances in science and technology and their application can make all the difference, can shape a new future rather than disastrously imitate the past. There is no need for today's developing nations to relive the trials of a nineteenth century–type industrial revolution and arrive at many of the technologically induced dilemmas of the twentieth century. All these pitfalls can be avoided if a truly rational approach to development is used, and with such an approach the average citizen of a developing nation can arrive at a living standard satisfactory to him, in tune with his culture and 'life-style' and not destructive of his environment.

To understand how this is possible we might look at the other side of the coin and see how the advanced nations might be 'redeveloped' through new outlooks of science and technology.

One of these truths is that future development cannot come about through the direct exploitation of nature or man. It must be the result of using the capital of growing knowledge, of rethinking our values and revising our priorities, of learning to do more with less by increasing efficiency, by the maximum recycling of resources, by being more imaginative and less restricted by tradition in design, by learning to manage the greater complexity that is involved in the systems thinking and action we must employ.

The solutions I see in resolving all these related problems of our age lie in recognising fully both the organic nature of human civilisation today and its inherent relationship with the natural environment that supports it. They lie in recognising that science and technology, the major forces behind the growth and intensification of these relationships, must be used to gain the knowledge we need to fill the important gaps in our physical and social intelligence and to adjust our discontinuities and coordinate our mismatched relationships. They lie in building the social institutions (and perhaps restructuring some of our existing ones) to direct science and technology wisely just as those institutions must extract intelligence and a certain wisdom from science and technology.

Actually, we are struggling with these solutions today, or beginning to. They seem so complex, so overwhelming at times that we wonder if we are not losing that 'race between education and catastrophe.' But I think we have at hand and are developing certain tools to help us win it. Some of these have arrived on the scene, historically speaking, virtually in the nick of time. I have often spoken of nuclear energy in this context because I believe that if we pursue its development carefully and apply it wisely it will provide a reasonably controlled population of reasonable demands with a virtually inexhaustible supply of power and at a time when we can anticipate the depletion of other sources of power

Nuclear energy, used wisely, will free man for eons from what Kenneth Boulding calls 'the Entropy Trap.' Abundant energy will allow us to save nature, not destroy it, by making a recycle civilisation possible. In such a civilisation only energy will be depleted and natural resources,

as we advance further in our knowledge of chemistry and physics, will become the building blocks of a world in which there can be endless variety without destruction.

Another technology that I believe is coming to the rescue of mankind – that may make mankind possible – is the computer. As the British cybernetics expert, Professor Stafford Beer, has pointed out, 'Society has become a complex organism, and it needs a nervous system.' We are now a global civilisation that depends for its survival on a growing influx of data which must be processed into information, stored, distributed and eventually upgraded to knowledge and wisdom. Today the computer is the vital link in that system. And in addition to telling us where we are, it can help us to shape our future by giving us the means to project and examine alternate futures. Through computer models we can 'look ahead' to the consequences of various courses of action we may choose. And thus we may choose more wisely.

There are many other sciences and technologies that offer great promise for the future. The earth-orbiting satellite is one of these. Equipped in various ways, it has the potential of giving us long-term accurate weather forecasting that may save many lives and much property. It can give us vital information concerning environmental conditions, the health of crops, the state of the oceans, the atmosphere, the location of mineral resources and other natural phenomena. And it can unite the world through satellite communications, providing education and a means of sharing knowledge and culture.

Perhaps the most significant shaping of the future may yet come from the shaping of man himself – directly

from the great advances now anticipated in the biological sciences. Here again, and perhaps most forcefully, we are faced with the moral challenge that science and technology create. When life itself can be directly controlled, moulded and even synthesised from basic chemicals, who will determine the nature, the direction and the ends of that life ? Are we preparing ourselves for such God-like responsibility ? In terms of cosmic time we are approaching it almost at the speed of light. We must think and plan and work and build our social institutions to manage this and other great responsibilities that our evolution is thrusting upon us. And we must do it now.

Man should be the standard of everything. In fact, he is a stranger in the world he has created. He has been unable to organise this world for the good of himself, because he did not understand his own nature. The enormous progress of the sciences of the inanimate things as compared to the advance of those of the living beings is one of the most tragic events in the history of humanity. The environment we have constructed by means of our intellect and our inventions is not adjusted to our size, not to our shape. It fits us badly. We feel unhappy in its surroundings. We degenerate morally and mentally. The very groups and nations, where the industrial developments have reached the pinnacle, become most weakened. They return to barbarism with a fatal speed.

Alexis Carrel

What is Science ?

JOHN ZIMAN

To answer the question 'What is Science ?' is almost as presumptuous as to try to state the meaning of Life itself. Science has become a major part of the stock of our minds ; its products are the furniture of our surroundings. We must accept it, as the good lady of the fable is said to have agreed to accept the Universe.

Yet the question is puzzling rather than mysterious. Science is very clearly a conscious artefact of mankind, with well-documented historical origins, with a definable scope and content, and with recognisable professional practitioners and exponents. The task of defining Poetry, say, whose subject matter is by common consent ineffable, must be self-defeating. Poetry has no rules, no method, no graduate schools, no logic : the bards are self-anointed and their spirit bloweth where it listeth. Science, by contrast, is rigorous, methodical, academic, logical and practical. The very facility that it gives us, of clear understanding, of seeing things sharply in focus, makes us feel that the instrument itself is very real and

hard and definite. Surely we can state, in a few words, its essential nature.

It is not difficult to state the order of being to which Science belongs. It is one of the categories of the intellectual commentary that Man makes on his World. Amongst its kith and kin we would put Religion, Art, Poetry, Law, Philosophy, Technology, etc. – the familiar divisions or 'Faculties' of the Academy or the Multiversity.

At this stage I do not mean to analyse the precise relationship that exists between Science and each of these cognate modes of thought; I am merely asserting that they are on all fours with one another.

Science is obviously like Religion, Law, Philosophy, etc., in being a more or less coherent set of ideas. In its own technical language, Science is information: it does not act directly on the body; it speaks to the mind. Religion and Poetry, we may concede, speak also to the emotions, and the statements of Art can seldom be written or expressed verbally but they all belong in the non-material realm.

But in what ways are these forms of knowledge *unlike* one another? What are the special attributes of Science? What is the criterion for drawing lines of demarcation about it, to distinguish it from Philosophy or from Technology, or from Poetry?

This question has long been debated. Famous books have been devoted to it. It has been the theme of whole schools of philosophy. To give an account of all the answers, with all their variations, would require a history of Western thought. It is a daunting subject. Nevertheless, the types of definition with which we are familiar can be stated crudely.

Science is the Mastery of Man's Environment. This is, I think, the vulgar conception. It identifies Science with its products. It points to penicillin or to an artificial satellite and tells us of all the wonderful further powers that man will soon acquire by the same agency.

This definition enshrines two separate errors. In the first place it confounds Science with Technology It puts all its emphasis on the applications of scientific knowledge and gives no hint as to the intellectual procedures by which that knowledge may be successfully obtained. It does not really discriminate between Science and Magic, and gives us no reason for studies such as Cosmology and Pure Mathematics, which seem entirely remote from practical use.

It also confuses ideas with things. Penicillin is not Science, any more than a cathedral is Religion or a witness box is Law. The material manifestations and powers of Science, however beneficial, awe-inspiring, monstrous, or beautiful, are not even symbolic ; they belong in a different logical realm, just as a building is not equivalent to or symbolic of the architect's blueprints. A meal is not the same thing as a recipe.

Science is the Study of the Material World. This sort of definition is also very familiar in popular thought, It derives, I guess, from the great debate between Science and Religion, whose outcome was a treaty of partition in which Religion was left with the realm of the Spirit whilst Science was allowed full sway in the territory of Matter.

Now it is true that one of the aims of Science is to provide us with a Philosophy of Nature, and it is also true that many questions of a moral or spiritual kind

cannot be answered at all within a scientific framework. But the dichotomy between Matter and Spirit is an obsolete philosophical notion which does not stand up very well to careful critical analysis. If we stick to this definition we may end up in a circular argument in which Matter is only recognisable as the subject matter of Science. Even then, we shall have stretched the meaning of words a long way in order to accommodate Psychology, or Sociology, within the Scientific stable.

Science is the Experimental Method. The recognition of the importance of experiment was the key event in the history of Science. The Baconian thesis was sound ; we can often do no better today than to follow it.

Science arrives at Truth by logical inferences from empirical observations. This is the standard type of definition favoured by most serious philosophers. It is usually based upon the principle of induction – that what has been seen to happen a great many times is almost sure to happen invariably and may be treated as a basic fact or Law upon which a firm structure of theory can be erected.

There is no doubt that this is the official philosophy by which most practical scientists work. From it one can deduce a number of practical procedures, such as the testing of theory by 'predictions' of the results of future observations, and their subsequent confirmation. The importance of speculative thinking is recognised, provided that it is curbed by conformity to facts. There is no restriction of a metaphysical kind upon the subject matter of Science, except that it must be amenable to observations and inference.

But the attempt to make these principles logically watertight does not seem to have succeeded. What may be

called the positivist programme, which would assign the label 'True' to statements that satisfy these criteria, is plausible but not finally compelling. Many philosophers have now sadly come to the conclusion that there is no ultimate procedure which will wring the last drops of uncertainty from what scientists call their knowledge.

This summary of the various conceptions of Science obviously fails to do justice to the vast and subtle literature on the subject. If I have emphasised the objections to each point of view, this is merely to indicate that none of the definitions is entirely satisfactory. Most practising scientists, and most people generally, take up one or other of the attitudes that I have sketched, according to the degree of their intellectual sophistication – but without fervour. One can be zealous for Science, and a splendidly successful research worker, without pretending to a clear and certain notion of what Science really is. In practice it does not seem to matter.

Perhaps this is healthy. A deep interest in theology is not welcome in the average churchgoer, and the ordinary taxpayer should not really concern himself about the nature of sovereignty or the merits of bicameral legislatures. Even though Church and State depend, in the end, upon such abstract matters, we may reasonably leave them to the experts if all goes smoothly. The average scientist will say that he knows from experience and common sense what he is doing, and so long as he is not striking too deeply into the foundations of knowledge he is content to leave the highly technical discussion of the nature of Science to those self-appointed authorities, the Philosophers of Science. A rough and ready conventional wisdom will see him through,

Yet in a way this neglect of – even scorn for – the Philosophy of Science by professional scientists is strange. They are, after all, engaged in a very difficult, rather abstract, highly intellectual activity and need all the guidance they can from general theory. We may agree that the general principles may not in practice be very helpful, but we might have thought that at least they would be taught to young scientists in training, just as medical students are taught Physiology and budding administrators were once encouraged to acquaint themselves with Plato's *Republic*. When the student graduates and goes into a laboratory, how will he know what to do to make scientific discoveries if he has not been taught the distinction between a scientific theory and a non-scientific one? Making all allowances for the initial prejudice of scientists against speculative philosophy, and for the outmoded assumption that certain general ideas would communicate themselves to the educated and cultured man without specific instruction, I find this an odd and significant phenomenon.

The fact is that scientific investigation, as distinct from the theoretical *content* of any given branch of science, is a practical art. It is not learnt out of books, but by imitation and experience.

Science is not merely published knowledge or information. Anyone may make an observation, or conceive a hypothesis, and, if he has the financial means, get it printed and distributed for other persons, to read. Scientific knowledge is more than this. Its facts and theories must survive a period of critical study and testing by other competent and disinterested individuals, and must have been found so persuasive that they are almost universally accepted. The objective of Science is not just to acquire information nor to utter all non-contradictory

notions; its goal is a consensus of rational opinion over the widest possible field.

In a sense, this is so obvious and well-known that it scarcely needs saying. Most educated and informed people agree that Science is true, and therefore impossible to gainsay. But I assert my definition much more positively; this is the basic principle upon which Science is founded. It is not a subsidiary consequence of the 'Scientific Method'; it *is* the scientific method itself.

The defect of the conventional philosophical approach to Science is that it considers only two terms in the equation. The scientist is seen as an individual, pursuing a somewhat one-sided dialogue with taciturn Nature. *He* observes phenomena, notices regularities, arrives at generalisations, deduces consequences, etc., and eventually, Hey Presto! a Law of Nature springs into being. But it is not like that at all. The scientific enterprise is corporate. It is not merely, in Newton's incomparable phrase, that one stands on the shoulders of giants, and hence can see a little farther. Every scientist sees through his own eyes - and also through the eyes of his predecessors and colleagues. It is never one individual that goes through all the steps in the logico-inductive chain; it is a group of individuals dividing their labour but continuously and jealously checking each other's contributions. The cliche of scientific prose betrays itself. Hence *we* arrive at the conclusion that' The audience to which scientific publications are addressed is not passive; by its cheering or booing, its bouquets or brickbats, it actively controls the substance of the communications that it receives.

In other words, scientific research is a social activity. Technology, Art and Religion are perhaps possible for Robinson Crusoe, but Law and Science are not. To

understand the nature of Science, we must look at the way in which scientists behave towards one another, how they are organized and how information passes between them. The young scientist does not study formal logic, but he learns by imitation and experience a number of conventions that embody strong social relationships. In the language of Sociology, he learns to play his *role* in a system by which knowledge is acquired, sifted and eventually made public property.

The 'Science of Science' is a vast topic, with many aspects. The very core of so many difficulties is suggested by my present argument – that Science stands in the region where the intellectual, the psychological and the sociological coordinate axes intersect. It is knowledge, therefore intellectual, conceptual and abstract. It is inevitably created by individual men and women, and therefore has a strong psychological aspect. It is public, and therefore moulded and determined by the social relations between individuals. To keep all these aspects in view simultaneously, and to appreciate their hidden connections, is not at all easy.

It has been put to me that one should in fact distinguish carefully between Science as a body of knowledge, Science as what scientists do and Science as a social institution. This is precisely the sort of distinction that one must *not* make ; in the language of geometry, a solid object cannot be reconstructed from its projections upon the separate cartesian planes. By assigning the intellectual aspects of Science to the professional philosophers we make of it an arid exercise in logic ; by allowing the psychologists to take possession of the personal dimension we overemphasise the mysteries of 'creativity' at the expense of rationality and the critical power of

well-ordered argument; if the social aspects are handed over to the sociologists, we get a description of research as an N-person game, with prestige points for stakes and priority claims as trumps. The problem has been to discover a unifying principle for Science in all its aspects. The recognition that scientific knowledge must be public and *consensible* (to coin a necessary word) allows one to trace out the complex inner relationships between its various facets. Before one can distinguish and discuss separately the philosophical, psychological or sociological dimension of Science, one must somehow have succeeded in characterising it as a whole.

The impact of Social responsibility on Science

It is not given to us mortals to perceive the full consequences of our actions. Moral responsibility is therefore an issue that cannot be decided by scientific procedures. When an evil is traced back to a cause that we have freely created, we can almost always produce an excuse.

The Escapes from Responsibility

'I had no idea that this would happen, Sir!'—thus, perhaps, Rutherford, for splitting the atom. 'It was all in a good cause, Sir!'—the discoverers of DDT. 'If I hadn't done it, Sir, somebody else would!'—nuclear fission, shall we say. 'They were going to do it, so I thought I had better do it first!'—the biological weapon makers. '*They* made me do it, Sir!'—a general excuse for all servants of all corporate bodies. 'We tried it out, and it *seemed* to work all right!'—the thalidomide tragedy. 'I didn't actually do anything myself; we just talked about it and the other chaps went and did it'—a compendium of

justifications for all academic research. 'Well, it does make rather a mess, doesn't it, but everybody wanted to play with our new toy' - which covers much of the pollution problem. And so on.

Every such excuse is valid, however essentially infantile. The scientist is not in the front line, pulling triggers and dumping defoliants. By definition, he is a Back Room Boy, employed to discover principles and to design devices, not to hurt other people with them, so you can't really blame him for what has happened. True enough; but if he had not made that misused discovery, or if he had imagined its consequences, or if he had not allowed himself to be employed by that evil corporation, then perhaps the tragedy would not have taken place.

In the complex of social institutions within which we try to make ourselves at home on earth, the mind and professional expertise of the individual scientist is not a negligible force. The enormous size of the technical community seems to guarantee anonymity and to countenance irresponsibility, yet the intellectual leader carries ten thousand of his colleagues with him in a 'break-through', and sets ten million humble labourers on a new course of manufacture, commerce and use. We scientists cannot take personal pride in the 'achievements' of our science and technology and simultaneously repudiate responsibility for its failures and abuses. We are either humble workers in the vineyard—or we are indeed the New Men come to make a better world.

The dilemmas of personal responsibility are not new, and the history of ethics tells plainly that they cannot be resolved. Think of the Inquisition – or of the revolutionary turned executioner – before you put your trust in an

ideology or a pledge of virtue or a Hippocratic oath. Gospels, social blueprints and other formlae acquire their legalistic interpreters until the call for peace becomes a war-cry and the stake is an instrument of mercy.

I see no salvation in resolves or resolutions, however aptly phrased and apparently benevolent. To accept them without reservation is essentially to abjure responsibility ; it is the abandonment of judgement and a flight from rationality itself. An innocuous pledge can do no good until it is called into question, when precisely the issue of interpretation in particular unforseen circumstances must be faced. It is then that we must rely again upon our spiritual and intellectual resources: the will to do good, the imagination of suffering, the rational calculation of the consequences of action or inaction.

The Making of Socially Responsible Scientists

Social responsibility in science rests therefore upon the way in which scientists are made. Whether or not we have the inborn talents for success in research, we are moulded by upbringing and education. But social responsibility is not a subject to be learnt from a course of lectures. It is not something one can practise ostentatiously, as an example to the young. It is an attitude of mind, a sensibility of the spirit implicit in an educational system, in personal relations, in institutional policies.

What is missing from the education of present generations of scientists ? First, they lack general education. They go out into their corporate laboratories as learned ignoramuses knowing all about nuclear magnetic resonance, or the physiological function of adenosine triphosphate, but without any grasp of history, of philosophy, of political thought or of economics – or of

other fields of science. The microbiologists scorn ecology, the nuclear physicists know nothing of warfare, the mechanical engineers are totally ignorant of the physiology of respiration, and so on.

In the mad rush to produce completely trained specialists on the cheap, we assume that they will somehow pick up the rest of the knowledge they need. How? From newspapers, from bar-room gossip, from television programmes?

We instil into our technologists the highest professional standards, so that they are rightly suspicious of the claims of anyone but an expert in their own field—and then we entrust them with tasks that demand expert judgement over many fields. How can the aircraft engine designer take responsible decisions about noise? That is not his field. There are 'acousticians', aren't there, to deal with that? We need science generalists, not just to run big business or to go into politics, but to do science itself.

Our specialized courses of study – pure physics, pure chemistry, pure biochemistry, even pure medicine and pure engineering – are absurd and nonsensical as a training for active life, whether in research itself or in technical development. The assumption is quite false that the clever schoolboy, drawn through the successive dies of primary school, 11-plus years of secondary school, O-level, A-level, university, B.Sc. Ph.D., etc., like a billet of steel drawn down into a mile of piano wire, can acquire incidentally all the detailed information he needs outside of such a speciality. The inter-disciplinary, technological, historical and economic aspects of our academic disciplines must be *taught*, positively, wisely, expensively and at length.

Passion of spirit, Rationality of intellect

Yes, in the end, it comes down to a passion of spirit but a very cool rationality of intellect. Teaching responsibility in science is also teaching science: the correct appraisal of situations and forces, the use of every bit of knowledge available, readiness to observe, interpret, experiment and theorise. Provided that we give maximum weight to genuine social needs and aspirations – *i.e.*, we treat people as people, not as abstract mouths, reproductory organs, sources of exertion or transportable packages – then we must use our heads to the full.

Responsibility in science is the use of one's scientific talents, not the pompous authority of one's name on a petition or a vulgar display of naive political prejudices.

Individual responsibility and Courage

Individual responsibility may demand personal sacrifice. It may mean a willingness to stand up and be counted, to earn public abuse, even the loss of office and employment. 'The blood of the martyrs is the seed of the Church', they used to say.

I do not say that the State is an abomination, nor that science is being used exclusively for wicked ends by powermad tycoons and politicians. In our democratic societies, there are means of resolving conflicts of goals that do not call for violence and ultimate martyrdom. Yet one must note that such conflicts are latent in the confrontations of transcendental knowledge by earthly economic and political forces.

The problems of individual responsibility in science are not trivial. They are not solved by wild movements

of protest by passionate students. The responsibility has to be exercised by scientists themselvest that is, by persons of sufficient maturity and experience to speak and act as experts in extremely complicated technical situations. This very maturity and experience can be acquired only by long years of purely professional activity as assistants and subordinates in large-scale enterprises, where the passions are sapped, the moral insights are dulled. All that we can do, I believe, is to sensitise and arm their consciences, sharpen their understanding of the world and its ways and exercise their moral faculties, in youth, so that they may comprehend the issues and have the courage to face opposition when the real battles have to be fought.

Scientific 'Antibodies'

But let us not despair. The historical answer to the tyranny and irresponsibility of individuals and institutions is not merely personal martyrdom, cunning accommodation, or the preaching of unheeded sermons. The wisdom of society creates the countervailing corporate power : parliament to curb the king, the courts to curb banditry, trade unions to curb the exploitation of labour, and so on. The 'balance of power' model, the adversary principle, the peculiar institution of 'Her Majesty's Loyal Opposition', are examples of a technique that could well be copied. If we have bodies of scientists dedicated to essentially irresponsible and selfish ends, of profit or power, then we must invent 'antibodies' to neutralise them.

Scientific responsibility in social issues therefore demands such debate, whether in the comparative privacy of the learned journals or in the form of the press or Parliament. In most cases, there is no absolute truth to be determiend : DDT is both a blessing and a scourge ; motor

vehicles are convenient, but noisy and dirty. A balanced report by a single expert commission, however well intentioned, cannot judge between conflicting opinions and priorities until each party has expressed, to the utmost, its own special viewpoint or interest.

A Society gets the Scientists it deserves

A country gets the scientists it deserves. A responsible society breeds, trains and fosters responsible scientists. An open market in ideas and political criticism is also open for technical attack and counter-attack. A free press, for example, ready to publish informed articles on scientific matters, may be the essential atmosphere in which kites may be flown as first signals of a storm of controversy.

The problems of technological progress are not, in the end, capable of decision by 'scientific' methods. They are problems of social priority, of aesthetic judgement, of taste of preference, of material and spiritual standards. The final arbiters must be the common people, as users and abusers of our pretty toys.

Let's not fool ourselves, though. Most 'political' and 'economic' decisions about technology are taken at first hand by politicians, businessmen, generals, and other socially powerful people. Until quite recently, these proud, self-confident and supposedly responsible chaps scarcely deigned to listen to scientific arguments at all; technical change was occurring at much lower levels in society than in their elevated world of political parties and personal profits. Now they have learnt something of the need for expert advisers, and of at least some sort of statistical evidence to support their intuitive wisdom.

Despite one's suspicions of the closed worlds that some such advisory groups can build about themselves, especially when protected by secrecy, one must encourage this development: for the moment we cannot have too much decent science in the government and in other organs of social action.

Scientific Responsibility for Tomorrow

The public adoration of the scientist, as the sage and saviour, is a thing of the past; now we seem to hear nothing but scorn for his pretensions and hatred of his arrogance. The movement to harness every technical expert to environmental studies or systems of engineering, to make him useful and safe – your friendly neighbourhood boffin could be as damaging as the older snobbery of pure science for its own sake.

Scientific knowledge and social action are not the same thing. Natural philosophy is not entirely for useful ends, despite the technological spin-off. If you try, too short-sightedly to press it into service for immediate ends, then you will rob later generations of its products. Countercyclically, I feel the need to preserve the collective skills, the expert knowledge, and the delicate social organisation of the scientific community from the pressures of an ignorant public, a shameless press, rapacious money-makers and opportunist politicians. A certain aloofness, a slight distance from everyday affairs may be the only way of preserving these islands of sanity in a crazy world, not as refuges but as watch-towers and safeguards against far greater evils.

That is the paradox : social responsibility in science must not be too concerned about today, for tomorrow also will come.

Need for understanding science

WARREN WEAVER

I wish to discuss four aspects of the problem of the interpretation and diffusion of science. First, I will say why science is important, even though this will involve repeating some truths that are rather obvious. Second, I will comment as to why the interpretation of science to the public is so difficult. Third, I wish to emphasize why this interpretation is so specially needed at the present time. And last, I want to set forth some more general reasons why the public interpretation of science must be carried forward continuously, interestingly but never trivially, accurately but clearly, humbly but enthusiastically, ardently but patiently.

Although the point may seem obvious, there is nevertheless real reason to ask why science is important. For, with the general public, science often receives respect which it does not deserve ; and fails to receive much of the kind of admiration which it richly does deserve.

The importance of science can usefully be considered at different levels. At the level of most frequent and most

tangible experience by the average man the key word is 'convenience' : and this word makes it clear that this sort of importance of science is not a very serious or profound one. Science, through its practical ally technology, contributes at every hour of every day to the convenience and comfort of life. The citizen of a scientifically advanced community has continuously available to him a whole host of devices. In many parts of the world, we have grown so accustomed to these conveniences that we forget that basic scientific discoveries made them possible. It is unfortunate, in a way, that the name 'science' is too frequently and too cheaply associated with all these minor paraphernalia of modern life. For although science makes possible these useful gadgets, science is not gadgetry.

But many of these devices may frequently be used to serve men in much more serious and significant ways. The telephone call may save a life, the automobile may be an ambulance or a police car, the air conditioning may be used in the surgical ampitheatre of a hospital, the radio message may be from the head of a great State. So at a higher level of significance science is a truly important servant of every man. One need only mention medicine, with the alleviation of pain, the curing of disease, the prolongation of life; and modern agriculture with its vitally important promise of more and better food, as major illustrations of these more significant ways in which science serves man.

Then at a broader level of impact, although not always at a deeper or more significant level, are the many ways in which science has by now become inextricably involved in all the economic and political aspects of modern life. Every alert and aggressive industry must

today carry on basic research, for otherwise it cannot move forward with new products, new devices, new outlets for capital expansion, and new employment opportunities. This symbiotic interrelationship between pure science, technology and the economic health of a nation is by now generally recognised. Convincing proof of this relationship can be obtained, from the most practical and unacademic sources – the pages of the *Wall Street Journal*, which evidence a clear and vigorous appreciation of the role of basic research, and the full page advertisements in the Sunday edition of *The New York Times*, seeking mathematicians, physicists and chemists to be employed by great corporations.

The involvement of governments in science is one of the major social, economic and intellectual phenomena of our time.

In speaking first of ways in which science serves the convenience of individuals, then of ways in which science deals with important necessities of groups of persons, and thirdly of ways in which science is broadly integrated into the whole texture of our present-day economic and political social structure, we have been moving from lower to higher levels of significance. But there remains one more upward step – and a considerable one.

For all of the scientific discoveries and developments which pass through a technological stage and then touch men tangibly and concretely, are, at least in the judgement of most scientists, at a lower level of significance than those triumphs of science which result not from the pressure of necessity, not from the demands of the market place, from a desire for profit or convenience or safety, but which result when inquisitive and disciplined minds

approach the intricate mysteries of nature and seek to understand.

That is to say, the true significance of science rests not on its practical achievements, be they trivial or great, but rather on the fact that the scientific mind, approaching the widly tangled confusion of nature, accomplishes an act of artistic creation when it discerns, displays and illuminates, amidst all the apparent complexity, hitherto unsuspected relationships of simplicity. This is the moment when man justifies his role as the culmination of all nature, justifies the cerebral machinery which evolution was so long in providing him with.

Mankind can hardly be very proud of the way in which it has handled many of the challenges of existence - goodness, or peace, for example. But when science has probed inside the nucleus of the atom, inside the gene of the cell, out to the surface of Mars and millions of light years further, then man can legitimately consider that he is bravely and competently at work to meet the challenge of the mysteries of nature.

Yes, science is significant enough. It is widely distributed over large portions of our planet, and it is invading the remaining portions with formidable speed. It largely determines our physical potentialities. It profoundly affects our lives, all the way from the trivial level of motorised kitchen aids to the deep level of moral concern as to our role in nature and our ultimate destiny.

Clearly then this is a major determining force in our modern society which every person ought to strive to understand. Lord Todd of England, one of the truly great organic chemists of our time and a chief science adviser of his Government, has said, "The past one hundred

years have certainly brought about a greater change in the material aspects of civilization than occurred in the whole previous history of mankind ... And all the changes that have occurred can be attributed to science and to the modern form of technology which is the application of the scientific method and the results of scientific research to the problems of industry, agriculture, medicine, defence and administration. As a result, science and technology now permeate almost every aspect of public and private life and they have had a profound effect on our social systems, which have been slowly evolving over many centuries. The trouble is that although science and technology advance very rapidly, social attitudes and social patterns are slow to change; and it is the disparity between the rate of change in science and that in social behaviour in its broadest sense that lies at the root of most of the stresses and strains in the world today."

But if science is so universally encoutered, why is science not also univesally understood ?

There are two basic difficulties. First, the average adult has a difficult time with today's science bacause his school training was not a very effective preparation for the science now met in adult life. And secondly, not only the newer ideas, but also the actual words used in science are in many instances unfamiliar and formirable : and when the popular interpreter employs similes and metaphors, and tries to substitute simpler and more familiar words and ideas, he runs the risk of serious misinterpretation.

We should be neither surprised nor dismayed by the difficulties in interpreting science. It should, however, be recognized that a burden rests not only on scientists

(who must accept a lager part of the responsibility for making their activities intelligible) and upon science writers (who must be willing to study more seriously the science they interpret), but also upon the public at large (who must not limit their appetite to the exotic, the spectacular, or the trivial, and who must be willing to do a little hard thinking.)

I turn now to the third of the topics I announced when I began – why is it so specially important, at this particular moment in history, that science be effectively interpreted?

On each Thursday afternoon some three hundred years ago, a group of gentlemen gathered at the Bull-Head Tavern in Cheapside, London: Sir Christopher Wren, who was primarily professor of astronomy at Oxford, but who also designed the military defences of London and many famous and lovely buildings, including St. Paul's Cathedral; Robert Boyle, who was a great physicist and who also was the author of the *Defence of Christianity;* Lord Brounker, a patron of all the branches of learning; Bishop Wilkins, who in addition to being a cleric was Master of Trinity College and an expert on Copernican theory; Sir William Petty, who was a political economist, a professor of anatomy at Oxford, and a professor of music at Gresham College; Pepys, the diarist and man-about-town; and at a later time our two great A merican Benjamins – Franklin and Thompson, the later better known as Count Rumford. There were in this group members of parliament, critics, civil servants, and pamphleteers. There were explorers and travellers, antiquarians, and *bon vivants*. They were obviously men of wide interests: men of both intellectual and physical vigour. These were men of curiosity, and men of parts. They met there, every Thursday afternoon,

to carry out experiments, to eat and drink together, but primarily they met there to discuss science.

The discussion must have been very vigorous, for certainly the eating was – with two soups with entrees of salmon, cod, smelts, oysters, turkey, chicken, lamb pie, ham, venison and beef, with fruits, jellies, syllabubs and almonds. And then a fresh start on a 'second course' with three kinds of game, asparagus, pear pie, and marrow pudding – the whole well washed down with beer, claret, and finished off with port and maderia, champagne, brandy and rum.

This was the beginning of the Royal Society Club, a group which, together with others, received from the King on 15 July 1662, the charter of The Royal Society, that great organization which has been the centre of British – and for that matter, much of western – science for nearly three centuries.

It is good for us to think about this group of men. They were no sheltered scholars, no narrow specialists. They were men of varied and of important affairs. They devoted themselves to an activity, the serious study of science, which is today less common and at the same time more important than it was then.

For to these lively spirits of the seventeenth century, observing as they currently could the great beginnings of modern science, it was nothing much more than an intellectual luxury for them to know something about the new ways of testing, of analysing, and of understanding nature. Science had as yet so little touched their daily lives and works that they could have, in fact, known essentially nothing about science and still lived well-balanced lives. The Industrial Revolution was to be

faced by their great-great-grandchildren, not by them. A citizen of those days could appreciate the epoch-making character of the Bill of Rights of 1689, and could have his opinions about the personal government of Louis XIV without making use of any facts from physics or chemistry. He could trim a candle or saddle a horse or despatch a servant with a handwritten note without getting involved in any scientific equipment.

The situation today is completely reversed. Science has become fractionated into dozens of complicated specialities, and the total sweep of scientific knowledge is so wide that not even a professional scientist can hope to be informed, even superficially, about all of science. But of much greater general social importance is the fact that science has today become so inextricably involved in so many problems – personal problems, neighbourhood problems, economic problems, national and political problems, world-wide problems – that no indvidual can react and respond intelligently to these problems unless he has some understanding of modern science. Some of these problems face the individual person: the parents of a handicaped child; the individual who smokes cigarettes and wonders if he should swear off; the young woman who wants to know the facts about birth defects and the risks involved in hormone therapy to increase or to eliminate fertility; the industrialist who wants to know the effect on his business of future developments in automation, the farmer who needs to know the total effect of new insecticides, the community that is considering its pollution problems; the citizens who must decide whether or not to spend billions on bomb shelters, how much of the national wealth should be devoted to space research, how much support should be given to basic research as

contrasted with technological development and, perhaps hardest of all, must decide what is the proper role of scientists in government.

There are perhaps individuals who still believe that questions such as these should all be answered by 'somebody else'. But for those less of us who deeply believe in the importance of the individual and moral rightness of democratic procedures, all such questions must in the long run be faced by individuals in their personal lives, and by individual citizen-voters in their public lives. To be sure, they will not individually ballot on the exact number of rads which constitute a 'safe' radiation dose from fallout, nor will they individually directly decide whether their government is to spend a very large sum on cancer research, or on boring a deep hole in the earth's crust, or on the construction of a super-energy particle accelerator. But nevertheless it is strictly true that, is the democratic process is to work in the modern scientific world, the individual citizens have to have available to them the scientific facts which will enable them to weigh evidence on such matters.

There is a further reason why it is so necessary, at the present moment in world history, to interpret science to the general public. This results from the fact that many, many millions of human beings located on large areas of our planet have up to now lived in agrarian and non-scientific societies or even under primitive circumstances. But all that is under rapid change.

More than 50 nations who have become new members of the United Nations, new in a formal political sense but most of them with histories which long pre-date my own country, are being forced by the necessity of present

circumstances to jump precipitously into the modern technological world. Without the benefit of a couple of centuries of leisurely adaptation, they must, in some instances, pass almost directly from relatively primitive cultures into a world of electronics, computers, automation, jet flight, nuclear energy, and DNA. Some of these emerging nations clearly must industrialize their economies if they are to be viable; and this means that they must, as rapidly as possible, learn about science.

To live, in the modern world, without some reasonable knowledge of science is to be critically handicapped in any attempt to understand many of the major forces which are shaping our present society. It is to have all the senses dulled, and not only dulled to what is going on in the world, but – and I come now to my last and major argument – to be dulled to the beauty and to the spiritual significance of science, unaware of the incredible but lovely way in which our universe is put together, unconscious of the inspring unity which binds together all life and all that is at the moment not alive, uninspired by the vision of man's new capacities to control his environment and to liberate himself for new and more noble destinies.

It is a sad pity that so many persons think of science exclusively in terms of the hardware – the devices – that it makes possible. It is unfortunate that those with a slightly clearer vision see science chiefly as the healer and the feeder. In the long run it will, however, be worst of all if men cannot be made to understand the essential inner nature of science.

There are some so misled as to view science as a sort of mechanical monster, grinding ever forward, producing terrible engines of destruction, forcing everything into

pull conformity with inexorable and soulless logic, reducing everything to baffling but all-powerful equations.

Scientists themselves are, after all, human beings; and many of them, especially the lesser breeds, have kept so close to their instruments that they have in some cases themselves been over-impressed by certain superficial aspects of science. Some of them are so foolish as to believe that science is in fact all-powerful, that it can be indefinitely precise and totally objective, that its techniques can solve all problems, that its philosophy is the only guide we require.

To correct those false views I view to be a major duty of those who interpret science to the public. For those false views separate science from the rest of life. If those views are correct, then the gap that Lord Snow sees between science and the humane arts would be an unbridgeable gap.

From the time of Roger Bacon there have been those who consider that the business of science is simply to collect a lot of 'facts' (hard facts, we often say, implying necessary permanency, accuracy and objectivity) and then construct a theory to explain them. That theory then is 'true': and all must bow before it.

But we now fully recognize what we should always have realized – first that we obtain so-called facts only through observation, and that the observer is himself an essential part of the fact-system, thus at one stroke destroying both ultimate precision and ultimate objectivity; and second, we know that elements of choice, presuppositions which have neither a factual nor a logical-analytical basis but do have both a personal and a cultural basis, enter into the structure of all theories and into the selection of the

group of 'facts' to be dealt with. The former of these two points is a major consequence of the developments in relativity and quantum theory over the past half century, and the more general aspects of what might be called the mirage of objectivity have been brilliantly dealt with by Michael Polanyi. The latter point has been developed by various writers, but I would specially refer to Gerald Holton's *Presupposition in Theories* and to Thomas S. Kuhn's *The Structure of Scientific Ravolutions*.

In the former of these references Holton analyses the decision-making process as it enters into the construction of scientific theories, and convincingly develops the thesis that 'the process of building up an actual scientific theory requires explicit or implicit decision such as the adoption of certain hypotheses and criteria of pre-selection that are not at all scientifically "valid" in the sense...usually accepted'. In his book, Kuhn argues that at any one period of history there is a conceptual and instrumental framework, agreed upon and accepted by the entire scientific community, within which has been developed the 'normal science' for that time. Within that framework, moreover, scientific research 'tends to be a form of puzzle-solving rather than exploration of the unknown'. Unexpected novelties – at least those of significance – occur only through breakdowns in the previously accepted rules. These breakdowns are encountered again and again, as the normal mode of scientific practice evokes crises which cannot be resolved within the then existing normal framework. Kuhn, as an historian of science, analyses the progress of physical science over the past three hundred years to furnish evidence for his central thesis.

The evidence furnished by both of these authors demonstrates the underlying unity which joins science to

all other aspects of our culture and emphasizes the conviction, now so widely held by scientists that, as Sir Cyril Hinshelwood has said 'Science, whatever else it may be, is a form of creative art'.

That our scientific knowledge progresses 'by unjustified (and unjustifiable) anticipations, by guesses, by tentative solutions to our problems, by conjecturcs', and that these conjectures, although they are controlled and refined by criticism, can 'never be positively justified', is a viewpoint massively and convincingly defended by the great logician and philosopher Karl R. Popper. Science proceeds, Popper says, not by proving that certain statements are correct, but rather by showing that certain statements are incorrect. If this explodes the myth, apparently comforting to some but basically frightening, that science is the austere custodian of unassailable truth note that at the same time it forces science to join hands with all other human endeavours - for we all learn by mistakes.

One must not suppose, since I have just referred to Popper, that it is only philosophers and logicians who recognize the true, flexible, tentative, imaginative, culturally determined, artistic, and essentially spiritual nature of science. I could quote supporting statements by many of the really great scientists of our day— statements, for example, such as those Robert Oppenheimer has made concerning the essential nature of present-day theoretical physics or I could with special appropriateness on this occasion refer you to the beautiful chapter entitled 'The Vedantic Vision' in a small but profound and lovely book entitled "My view of the world", by the late Erwin Schrodinger, whose physics earned for him a Nobel Prize.

Let there be no misunderstanding as to why I have made these comments about the essential nature of science. Surely I have not done so to detract in any way from the practical value of science, nor to depreciate the magnificent successes of science. But these very successes, when viewed superficially and when over-valued as they can so easily be, tend to separate science from the rest of men's lives. Whereas the great need, as science marches forward, is to assure that science be merged into a mutually advantageous companionship with all of the humane arts, with philosophy and with religion.

Let me give, in a highly condensed form, one illustration of the kind of useful interrelatedness I have in mind.

We are all very familiar with the standard description of the experimental method which science began to envisage over three centuries ago, and which was so amplified after the development of adequate instrumentation. Scientists, using that method, can formulate problem, can plan experiments to reveal facts bearing on the problem, can analyse these facts, can devise theories, and can set up new experiments to test the theories – all this in a never-ending cycle of improvement.

No longer a slave to the superficialities accessible to crude observation, the scientist could now safely use hunch, intuition, imagination, and inspiration. He could properly be motivated by curiosity and sustained by courage. He could risk these informal aides because the technique subjected all conclusions to the critical test of experimental fact.

Although the value of the experimental method has of course been universally recognized, I do not think it has been properly emphasized that this method freed

the scientist to live the creative life of the artist. For the scientist, with no worry about the unprovable, could on the one hand now be guided and sustained by his faith in the reasonableness of nature and in the discovery of nature's laws, and on the other hand he could work with a perfect interrelationship between licence and logic. For in fact the scientific method furnished him with a solution to the problem of the relationship between freedom and discipline. He was completely free to try anything, and the method would correct all his mistakes and gently guide the next adventurous step.

Einstein once remarked that the most incomprehensible thing about the universe is that it is compehensible. Not by any means has all of the incomprehensibility of the universe been clarified by science. The creative arts and religion - especially the latter - are responsible for illuminating and enriching vast fields of experience inaccessible to science.

The capacity of science progressively to reveal the order and beauty of the universe, from the most evanescent elementary particle up through the atom, the molecule, the cell, man, our earth with all its teeming life, the solar system, the metagalaxy, and the vastness of the universe itself, all this constitutes the real reason, the incontrovertible reason, why science is important, and why its interpretation to all men is a task of such difficulty, urgency, significance and dignity.

The love of anything is the fruit of our knowledge of it, and grows as our knowledge becomes more certain.

Leonardo da Vinci

Science and Scientists in Today's Society

JEAN-JACQUES SALOMON

There has always been an impact of science on society, and there has always been an impact of society on science. even in the days when science as we know it, did not exist. Then it was philosophy, the science of sciences, which exercised an influence on society and society influenced it ; knowledge has always been bound up with the social system in which it develops and which it in turn helps to form.

No doubt in the time of the Greeks, before science had proved itself, it was possible to be sceptical. Today, when science has proved itself, far beyond the dreams of Bacon, Descartes or Newton, all scepticism is ruled out. But we find that among the general public, among the young, and even among scientists, science breeds and nourishes nihilism.

Science has so amply fulfilled its promises of application that a suspicion hangs, not over what it *is*, but over what it *can do*. Not only has science become a political

affair, but many people look upon it as the ally of bad politics. Even some scientists think it is in service of evil and no longer the irrepressible instrument of progress and happiness.

In the conclusion to his book on the history of relations between science and government in the United States, A. Hunter Dupree wrote in 1957 : "The mighty edifice of government science dominated the scene in the middle of the twentieth century as a Gothic cathedral dominated a thirteenth century landscape. The work of many hands over many years, it universally inspired admiration, wonder and fear." It is in the United States that science has found itself endowed with the most impressive cathedrals, has enjoyed the biggest throngs of the faithful and has acquired the most effective power of persuasion ; but all industrialised countries, since the Second World War, have raised temples with similar ambitions.

Their monuments were not necessarily "the biggest in the world", but they were none the less vaster than anything previously built, bigger in the size of the buildings, the number of scientists, the magnitude and variety of equipment, the amount of resources invested, and noted for the spectacular character of the results they achieved in such a short lapse of time. Thanks to science, everything seemed possible. True, the cloud of Hiroshima raised briefly some misgivings. Oppenheimer said to a visitor in 1956, "We have done the devil's work. Now we have come back to our real job, which is to devote ourselves exclusively to research."

And yet, ten years after this period of unprecedented growth, the cathedral of science is showing cracks every-

where, as though the very foundations on which it was erected were threatened. Enchantment has been followed by disenchantment. Accused of being associated with war and the deterioration of the natural environment and social structure, science finds itself under fire on all sides.

It is attacked from the right by those who denounce it as the costly pastime of mandarins who care nothing for economic return or industrial development; from the left by those who charge it with being the instrument of military and industrial domination, an instrument which pays no attention to the real needs of society and which is all the more pernicious in that it has helped to promote and satisfy imaginary needs.

Our civilisation has developed on the assumption that the progress of knowledge is good in itself because knowledge liberates, and by its very essence, contributes to the good of mankind. But the triumph of rationality seems to stand reason on its head; reason becomes the support of the irrational. The conquest of the atom plunges us into the balance of terror; the escalation of military power, far from increasing security, multiplies new threats with planetary implications; the discoveries of molecular biology open up the possibilities of manipulating heredity.

Man walks on the Moon, but comes back to find that the problems of Earth are still outstanding and that disequilibrium is growing; two-thirds of mankind has to cope with underdevelopment with less than five per cent of the world population of scientists and engineers. Yet while these less favoured societies dream of factory chimneys, saturated motorways, and ribbon-developed towns, the advanced societies confused, talk of a moratorium on

discoveries and a ruturn to the idyllic nature of Rousseau's man before the progress of science and the arts.

What has happened to make suspect the institution that most strikingly embodies the rationality of the West, and to turn it into a political affair ? Traditionally, politics has been a problem for science, but science has been no problem for politics. What has led to the difficulties, tensions and conflicts which characterize the relationship between science and society and which present a challenge not only of politics to science but of Science to politics ? It is as absurd to hold science responsible for what it has created as it is to expect it alone to provide the solution to the problems with which we are faced, both today and in the future.

Of course, a moratiorum on knowledge is absurd ; science has a history and one does not stop history. There is a great difference between the moratorium proposed by Newton to Boyle and the desire to direct research towards objectives which conform to the wishes of the community. The difference is that research has become, whether scientists desire it or not, a political affair.

What must properly be called the ideology of science forbids thinking of it in the equivocal terms of politics ; the discourse of science is neutral, a neutrality guaranteed by the objectivity of the method which presupposes rigour attention to facts, respect for proof. Nothing seems more alien to science than that "tale full of sound and fury" which is politics. The fight against authority, religious, economic or political, is no less a part of the history of science than are its theories and discoveries.

In our day, the tension has become dramatic. Science desires to confine itself to pure reason, but the sciences have become a social institution, and such institutions are

not necessarily governed by pure reason. In the eyes of governments, science is a national asset, a decisive factor in the balance of power, and an indispensable tool in the exercise of government itself. Scientists can no longer profess their indifference to the political use which is made of their discoveries.

Until recently, military research was content to adapt civil technologies to the needs of war, and this required no radical innovation either for science or for politics. Then during the Second World War, scientific research was used for the first time as a source of new technologies whose influence could be decisive not only on the conflict but also on the whole postwar period. The authorities, therefore, could no longer leave science to itself; they had on the contrary, to force the pace of discovery and innovation – and science, mobilised in wartime, continues to be mobilised in time of peace. The mobilisation of science is the subject of permanent arrangements, scientific research is organized, co-ordinated and even planned by governments. That is why the return to the exclusive service of research, of which Oppenheimer dreamed, is a fantasy, a nostalgia for a bygone age; history has burst into the serenity of the laboratories and is there to stay.

Governments can no longer do without science if they want to meet their needs, which have been multiplied, enlarged or created by the development of scientific techniques. They must include scientists in the formulation and execution of policy, as counsellors, administrators, diplomats and strategists. If science, for its part, sets up at the heart of politics, it is because it, too, cannot do without the State,

There are no longer any Maecenas or private foundation at hand to bear the cost of the capital investments

in needs, which, by definition, are infinite. The change of scale which started with the Second World War has placed science in a position of growing dependence on government; policy *for* science has become inseparable from policy *through* science.

An age of science which could be called classical, in the sense that its values were imposed exclusively by reference to truth, has closed with the promises of rapid applications which it is now in a position to keep. Scientific research pays no less dear than other activities for the links it maintains with the industrial system. Abundance has its counter-part in organisation, programming and planning.

The quantitative change of which research activities have been the theatre since the Second World War has been reflected in a qualitative change; from an ideal, a vocation, a culture limited to a chosen few, science has become a mass profession; as the source of innovations which can be rapidly exploited, it forms an integral part of the production system. In the eyes of some scientists this change seems like a betrayal of the ends (and the interests) of science, in so far as it should be concerned solely with the pursuit of truth. The horizon of utility under which it has blossomed compromises it, alienates it and, in a word, prostitutes it.

In reality, the natute of modern science and the structure of the industrial system combine to make scientists and politicians inevitable partners. There is no need to think up a conspiracy to see that scientific research depends on the objectives pursued by a government, and it is a highly romantic view to attribute to scientists more disinterested intentions than those of other

mortals. No doudt the quest for power, or fortune, is not their main goal, but it so happens that, by their function, they also encounter in the course of their career power and sometimes, fortune.

The scientist who questions himself about the consequences of his work cannot evade his responsibility. He can do so only by proclaiming that the theoretical function of science has nothing to do with its practical function.

It is not enough to solve the problem of over-population by perfecting contraceptive pill. The public must also be initiated in its use, especially those for whom over-population is a question of life and death. Evil as well as good may come of progress It would be too convenient for scientists to shut themselves up in their laboratories for the pleasure of doing research without recognising that, by their very research work, they are both producers and consumers of social change; consumers, because, after all, they depend on the wealth granted to them by the community; producers, because they transform this wealth into discoveries which are factors of change, On this point, at least, Marx was right; knowledge has become a factor of production, and if it has done so, it is because it is scientific knowledge.

Does that mean that the responsibility of the scientist gives him special competence in the political field? Most certainly not. The scientist is not an expert in politics; his competence in his own field gives him no greater authority in other fields than any form of technical skill. Objectivity is not transferred to human affairs by the mere fact of applying scientific methods to them.

Among scientists who make pronouncements on political problems there is often a certain naivete in thinking that value judgments and ideological options can be reduced to clear and precise terms. In a political combat the scientist is no less partisan than the militant who has no access to scientific language. The special characteristic of positivism is to imagine that it is possible to work out an applicable operational technique in the presence of conflicts and opposing values. But it is clear that, whatever the progress of the mathematics of decision, they will never succeed in formalizing the data and the choices of the political universe.

The scientist who intervenes in urban politics is no better armed than any other citizen to settle the problems of the city. But he is at least better armed to throw light on the problems connected with the role of science in the city. Here lies the whole foundation of his social responsibility. In this capacity, and on pain of complicity, he can and must effectively carry weight in political decisions.

So long as theoretical activity could be divorced from its applications the scientist owed service solely to scientific truth. Today, when knowledge can no longer be distinguished from its consequences, the ethics of his profession demand from the scientist a new duty, namely that of informing society of the implications of what he is looking for and what he finds. There can be no science without conscience.

If it is true that modern technology is wholly dependent on science, then it is the function of the scientist to be the conscience of technology. To inform, to educate, to warn. In the name of the ideology of science conceived

as the discourse of truth, the scientist is duty bound to denounce and fight what he conceives to be the misuse of science. It is only at this price that the priests officiating in the cathedral of science will cease to be confused with the merchants in the temple.

Cathedrals bear witness not only to the anonymous workers who built them, but also, and indeed primarily, to the faith they are designed to shelter. Scientific research is a religion which calls for faith, a rational faith. Like every religion, it must have its prophets, a college of apostles and the heart and soul of a whole people. It must also have its martyrs. But one could also add that it includes, like all religions, its share of magicians, simonists and time servers.

If it is true that faith is compromised by the merchants in the temple, then the priests of science should dissociate themselves from those who reduce the practice of science to a purely utilitarian adventure, to works and objectives in which it can no longer recognize itself. For, if science is a sort of faith, it is so because first and foremost it stakes everything on the power of reason to render account of the world and to mould it to human ends; unless scientists assume full responsibility the whole institution of rational knowledge will finally be compromised.

The end of *laissez-faire* in the relations between science and politics cannot mean there is now unlimited freedom to innovate; it is a matter for scientists themselves to contribute to the control of technical innovation, that is to say, to bring weight to bear on political institutions to ensure that the criteria for the support and exploitation of science are not based solely on output, profit, and short term prospects.

Otherwise, by dint of being associated with the merchants in the temple – most of whom, moreover, are nowadays arms merchants – scientists will be implicated in the erosion of the faith they profess, and the disappearance of the scholar, who is the conscience of science, will deprive the cathedral of all human meaning.

The purpose of scientific studies is to discover the truth about things and the patient workers in laboratories are as much imaginative creators as poets and philosophers. Those who help us to cut across mountains, to collect waters over thousands of miles to irrigate barren tracts and make them blossom, to subdue the elements of nature to the uses of man are benefactors of the human race. In a country like ours, where there is a vast amount of dirt and disease, poverty and uncleanness, the case for the spread of the scientific spirit and habits cannot be overestimated. The gifts of science help to make life fuller, wider, healthier and richer in comforts and interests and in such happiness as material things can promote.

If science is being perverted from its natural purpose, if it is used not for the happiness of mankind as a whole, but for private profit and public destruction, it is not the fault of science or the scientists. If there is chaos in the economic world, if cows are slaughtered for manure, if wool is used for roadmaking, if coffee is burnt and wheat thrown into the sea, while there are men and women undernourished and badly nourished it is not the fault of science. If the political world is anarchical, if scientific weapons are used for destruction and human slaughter elevated into a cardinal centre, it is not the fault of science. One of the greatest scientists of all ages said : 'The present troubles of the world are due to science having advanced faster than morality ; when morality catches up with science these troubles will end' (Einstein). Our progress is not integral if moral advance does not accompany scientific achievement. The problem of our age is the reconciliation of science and wisdom in a vital harmony.

S. Radhakrishnan

Science and our Future

W. F. G. SWANN

In the past, the life of nearly all mankind was spent in a struggle for existence. Mother earth demanded much tribute in the form of labour as payment for the fruits which she yielded. Labour was the necessary payment of man to nature for his existence, and in turn, the potentiality of man for giving labour represented a natural element of his wealth and so a guarantee for his existence. From the dawn of history almost until the present day he lived by what the earth gave him spontaneously, and in the sweat of his brow he toiled from morn to night to collect the gift; for the gift was made in meagre amount and he sought no means to expedite it. Such ingenuity as he possessed was engaged in segregating to himself as much of the gift as he could at the expense of the greater majority of his fellows, who, since there was not plenty for everyone, must spend all strength in the struggle for mere existence, with little of what we call happiness, and with little apparent reason for the labour other than the perpetuation of a monotonous existence from one generation to another. What little there was in the way of scientific

discovery was housed in large part in the dens of the charlatans and sought close companionship in the black arts.

And then, barely more than a century ago, a new page in the drama of history opened. The power of steam was harnessed and the time and burden of travel shrank. Soon came the era of electricity, an era in which each successive discovery added further to the comfort of mankind. More and more of the world's work was done by the forces of inanimate things rather than by the toil of the arm and hand. The seeker after truth had tasted the blood of conquest and was encouraged to enter new domains. Science spread its wings over all nature, and the search for new things was no longer a dubious occupation, a companion to witchcraft, but a legitimate and recognized ambition of the curiosity of man. As if in reward for such recognition of pure idealistic research, it turned out that investigations, started with no immediate utilitarian purpose, and without the hint of a promise of future service to mankind, yielded, in actuality, fruits in such service far beyond the wildest dreams of the investigator.

Today, we stand heirs to all this wealth of nature's resources. The labourer of today has at his disposal conveniences which no king possessed a hundred years ago. I think it would be safe to say that if King Solomon could suddenly have had installed in his house an oil furnace, a cooling system, electric light, and a telephone with the other end at the residence of the Queen of Sheba - if he could have gone careering through the streets of Jerusalem at fifty miles an hour in an automobile - he would prabably have been renowned in his time for possessions to an extent far beyond even the renown recorded to his

credit in Holy Writ. Today, even the humblest artisan is possessed of conveniences which, seemingly, would have outshone all the luxuries of the world of ancient times. Yet, he who possesses these things today is often an unhappy and disgruntled person, with a grievance against something or somebody as his main source of mental exhilaration.

And if in the midst of all this potentiality for happiness man is still unhappy, what is the reason for his state? What does he seek for his goal of happiness and why can he not attain it? Man is an active animal. Through the thousands of years of his history he has become accustomed to count the gains of his labour, and the gains have, for the most part, consisted in the past of accumulation of the means of existence to succour him when he could no longer labour, or better still, a means of existence without the necessity of the enforced labour of the slave. Now, as more and more the world's work is being done by machines, we are reaching a stage in which not only is the amount of toil necessary for existence reduced, but in which the perpetuation of toil, with the greatly enchanced efficiency which the machine age has brought to it, has produced a new realm of strife, a strife between the machines, whereby the equilibrium of life becomes upset to a degree in which the little that man needs for his existence fails to reach its proper goal of distribution on account of the turmoil of activity created by the operations of inanimate things.

In the last analysis of the trend towards perpetual increase of so-called utilitarian activity beyond a certain limit, my mind turns to the thought of some great Mogul who, having gained control of the running of the affairs of the world looks down upon our civilization and,

whipping up the speed of things, while egged on by the increasing efficiency of the appliances which man has designed, comes to the conclusion that in comparison with these appliances man himself is a very inefficient animal and ought to be abolished. If I ask this Mogul what the purpose of this marvellous organization would be without man in it, I can imagine from him no reply other than one to the effect that it constitutes a beautiful, smooth-running machine which, like a picture or a symphony, is an end in itself, and that he likes to see it run. But, with man gone, there is nobody but the Mogul to enjoy it. To the fundamentally and fatalistically morbid I present this Mogul as, in all verity, a deity guaranteed to keep them lusciously miserable for the life time remaining to them. Under another chapter I might signify the aim of this being in the title " The Devil in Control. "

If I plead with this devil to let man live, I surmise that he may object on the grounds that man may tamper with the machinery which is now in perfect running order. Here I have some sympathy with this devil. And so I make a bargain with him to the effect that man may be allowed to live provided that he will guarantee never to do anything which, in the sense of the old meaning of things, can be called useful. Man shall not be deprived of the inspiration of continuing his researches in science. He shall be allowed to continue the enrichment of the arts. He shall be kept as a kind of domestic pet of this devil, with no duties other than those concerned with amusing himself.

And so I suggest to this devil that since man has, as it were, worked himself out of a job, so that his potentiality for labour no longer guarantees his right to exist, he be pensioned off, and allowed to pursue the

rest of his existence in play, confining what were formerly his utilitarian efforts to oiling the machinery.

Now, of course, I do not wish to imply that we have yet reached the stage at which the ideal I have cited is a practical one. And yet I do envisage this ideal as a limiting one to which the machine age should naturally tend. It is what the mathematician would call an "asymptotic ideal"; something which is continually approached but never actually realized. The point which I wish to emphasize, however, is that even today it may be true that many of the troubles of our economic existence lie in failure to recognize the trend toward this ideal and the necessity of a continual sensitivity to it. In the attainment of such an ideal, wealth no longer has meaning for the aims for which it exists are already attained.

However, if I take to mankind this treaty in which this devil like potentate has acquiesced, I surmise that there will be many who will be unhappy in the thought that their future activities will lie outside of the realm of that which they have been accustomed to regard as useful. In an attempt to appraise the ultimate value of things, perhaps I may be pardoned for citing here an illustration which I have given elsewhere concerning a supposed conversation between a pure utilitarianist and an artist of the "art for art's sake" type. The conversation concerns the pictures which Michelangelo painted in the Vatican.

"Of what use are those pictures?" asks the utilitarianist. "They do nobody any good and only wasted the time of Michelangelo, who painted them."

"And what kind of creative work would you regard as of use?" asks the artist.

"Well, the development of the steam engine or the automobile," says the utilitarianist.

"But why are these of use?" asks the artist.

"Because they enable one to move about faster and get more done," says the utilitarianist.

"But why move about faster and get more done ?"

"Because by doing so you create wealth for yourself and others ; you save time and are enabled to enjoy more leisure," is the rejoinder.

"And what is the use of money and leisure?" asks the artist.

"Is it not rather boresome to have nothing to do ?"

"Oh, it is not necessary to do nothing", is the reply. "You can travel and enlarge your mind."

"But," says the artist, "what is the good of travelling ? You only get seasick and very tired."

"Oh," replies the utilitarianist, "it is a wonderful experience to travel. You can go, for instance, to the Old World and visit all those places of classic renown : Paris, Venice, London."

"But," says the artist, "is that not very disturbing ? I hear that many of these places are unsanitary. The food is not what you are accustomed to, and sometimes the people are not overfriendly."

"Those are but small matters," says the utilitarianist "they are far outweighed by all of the other riches you fall heir to. You can bask in the exhilarating sun of the Alps. You can drink in the beauties of the Mediterranean. You can visit ancient Rome ; and by the way, when you are there, do not fail to see those marvellous pictures which Michelangelo has painted in the Vatican."

And so I have wondered if we should be far from the truth if we should maintain the thesis that the only ultimate excuse for the existence of the things utilitarian is that they provide the means whereby we may enjoy the things non-utilitarian.

And so in the life of mankind one recognises two types of activities, types which may crudely be described as utilitarian and those which are non-utilitarian. In the ages which have passed there has been, for the most part, no danger of saturation as regards the former. Nature claimed all the effort that man could give as the price of his existence, and the second category of effort – the non-utilitarian – was reserved for the favoured few who, by the chances of fate, had managed to acquire an exceptionally large proportion of the fruits of the labours of their fellows. As the discoveries of science have revolutionised the plans of the world's work, we have reached the stage in which the very continued effort of man in the utilitarian field can bring about lack of equilibrium of such a kind that the residue available for the individual needs, either through faulty distribution or a lack of appropriate planning, is less than it would have been if the world had been less active and if man had worked less hard. A condition, however, in which people are idle because, if they worked more, they would upset the equilibrium, is not a healthy one for the race. He who is forced to work that he may survive, feels a grievance against nature, but he who is condemned to inaction lest his efforts cause trouble has an even greater grievance.

The solution of the difficulty is, I think, to be found in a proper organisation of utilitarian efforts to the maximum degree of efficiency in such manner that the amount of it is just sufficient and no more than sufficient

for the needs of healthy existence. We must then turn the spare time of man into a non-saturable domain, a domain in which the effort of one section does not render abortive the efforts of another.

We must, in fact, turn this surplus effort into the non-utilitarian field. If, in the utilitarian domain, I improve my organisation in the sense that I can create a product with less and less of the utilisation of manual effort, I may do somebody harm unless the increase of my efficiency is accompanied by a corresponding economic adjustment. If, however, in my spare time, I play the violin and I continue to improve, it does not follow from my improvement that my neighbour, who plays the piano, will deteriorate in his performance.

In the past, we have been too accustomed to assume that support of science is justified only because of the utilitarian advantages to be expected of it. Today we are approaching the other extreme, where man is invited to keep his hands off the machinery but, if this extreme is to be accompanied by lack of provision of the means for the continuation of effort which is not accompanied by utilitarian ends, then there is much to be said for the decree of that devil to whom I introduced you earlier and who sought the complete abolition of man as an inefficient parasite upon the workings of the universe. In the old days the cry of "art for art's sake" or "science for the sake of science," was supposedly the cry of the fanatic. In the furture this cry, or the cry of "something for something's sake," will be the cry of all mankind as a reason for his existence, and as an end in itself. For it, relieved of effort directed towards utilitarian ends, man becomes ashamed to do anything because of a suspicion as to its lack of usefulness, then he becomes, in all verity,

the most colossal bore in the universe, and my good devil will do well to abolish him,

In the last analysis, is not happiness, in the broadest sense, the goal of mankind ? It is the promised land to which science has brought us and which the future invites us to cultivate.

One trouble concerned with our existing civilisation lies in the fact that we have invented so many things for our enjoyment and entertainment, and we have invented so many labour saving devices, that the mere operation of all these devices seems to leave less time than was available to a person 150 years ago to enjoy in life the things which really give permanent enjoyment. It is a wonderful thing to listen to the radio the first time we hear it. After a time it becomes a habit, so that the machine is left to exercise its noise making potentialities when nobody is present in the room.

All of these devices give, for the most part, only superficial pleasure and by that very token give a pleasure which soon wears out and leaves the subject with a feeling of discontent. I would suggest that lasting pleasure is only obtained when the mind is active, or when there is consciousness of development of some kind in the subject.

Earlier in these lines I have lamented the fact that man, the inheritor of wealth beyond the dreams of the kings of olden times, is often an unhappy individual, and often he is unhappy when his state is such that he is among the favoured group whom the economic battles of our times have left unscathed. Happiness itself is a strange thing. I do not believe that it is determined by the *status quo* of the individual, no matter how high the level of that *status quo*. It is determined rather by the progress,

of the individual from one state to another. He who, while playing the violin in the capacity of an amateur, has succeeded by his effort in surmounting some difficulty which had previously baffled him, is happier at the moment as a violinist than is Kreisler, for in this, as in all things, there is more happiness in the consciousness of improvement than in the finality of attainment. Never will there be an age in which a being of the state of development of man can expect happiness except as the result of progress through effort expended on something; and those who expect happiness from idleness in the *status quo* I commend to the company of their spiritual relative, the cat, whose maximum of contentment seems to be reached in a state only sufficiently different from that of slumber to admit recognition of the outside world by the maintenance of a purring sound.

Faith is the basis of religion ; reason is the underlying principle of science. When faith is artificially bolstered by false reasoning, or when reason is irrationally circumscribed by faith, chaos and confusion is the inevitable consequence.

I. Berenblum

Our earth has grown so small. And man so great. The Earth knows nothing of its smallness - nor does Man of his Greatness.

Hugo Boyko

Science and Life

J. B. S. HALDANE

What is life? One of our greatest difficulties in answering a question like this arises from language. We use words, and are inclined to think that a thing must correspond to every substantive. Now some substantives stand for things; for example, bricks, water, and coal-gas are things. Others are more doubtful. For example, a wave moves over the sea. We say that it is the same wave now as five minutes ago, but the particles of water in it are quite different. A tune has even less claim to be called a thing. It may be being less claim to be called a thing. It may be being played in several places at once, or nowhere. And some substantives like greenness or cleverness stand for qualities which no one except a few philosophers suppose to have any existence of their own.

Where does life belong in a classification of this kind? When a man dies we say that he has lost his life, or that life has gone out of him. Is that just a metaphor? Is death the loss of something, or merely a change of state, as when a snowman melts, or a pattern is disarranged? The first people of whose ideas on this subject we know

anything thought that life was the same as breath. But we know that the breath consists of gas, which can be made into a solid or liquid, and also that many living things do not breathe. Life is certainly not a kind of matter. When a man or an animal dies he does not lose or gain in weight. Nor is there any measurable loss of energy. The heat gradually leaves the body, but it is doing so throughout life. A dead body cools because no more heat is being generated inside it, not because anything measurable leaves it at the moment of death.

Our ancestors thought that anything which moved itself was alive. And before the days of machinery that was quite a good definition. But a machine such as a motor-car or a steamship moves itself, and as soon as machines which moved themselves had been made, people asked, 'Is man a machine?' The philosopher Descartes thought that both men and animals were machines, but that the human machine was partly controlled by the soul acting on a certain part of the brain, while animals had no souls. And some scientists think that life is just a very complicated mechanism.

Though we shall not accept this theory, there is a good deal of truth in it, and it is worth examining. A great many of the differences between animals and machines are due to the mere fact that animals are so much more complicated. The higher animals are built of cells which have a life of their own. Now in a dog's brain there are something, like fifty million nerve-cells, each connected up with many others, and in touch with the outside world by nerves leading from the sense organs such as the eye, and to the muscles. The nerve from a 'dog's eye consists of at least a hundred thousand fibers

each of which can transmit a massage independetly of every other like a number of telephone wires running side by side. Further, each cell consists of many thousands of parts each of which is different from every other. Such a complicated machine may be expected to have properties not found in any machines we know. Our best machines regulate themselves to a great extent. Even ordinary steam engines have governors. Perhaps an animal is only a very perfect self-regulating machine.

Why, should we not 'go the whole hog', and say that animals and plants are just machines, adding, if we like, a soul in the case of man, and perhaps some of the higher animals ? First, let us ask what we mean by a machine. I think we mean a system capable of performing some function (say making a noise or cutting wood) which is made up of replaceable parts, and which can be fully understood when we understand about these parts. For example, if any part of a motor-car is broken, a new one can be got to take its place ; and an engineer who knew enough about the parts could tell you a good deal about the car's behaviour. The opposite to a machine is an individual, something which from its very nature cannot be taken to pieces and put together again. Most plants are much more of machines and less of individuals than men or dogs. They can be cut in two and each part will live. Parts of different plants can be grafted together, and so on. But the parts of a man or a higher animal change their nature very quickly when taken asunder. Each part depends on the other parts to keep it alive. So an animal is in some ways a machine and in some ways an individual, and the science of biology consists largely in finding out how much of a machine, and how much of an individual.

Again, if animals and plants are machines, they are self-regulating, self-repairing, and self-perpetuating machines. A good example of the self-regulation is that of the human temperature, which is so steady that a small rise or fall is a danger signal. If we get too hot, the blood flow through our skin is increased so that it loses more heat, like the radiator of a car. If this is not enough we begin to sweat. We also take off clothes, go into cool places, and so on. The most obvious examples of self-repair are the perpetual renewal of the skin, and the healing of wounds.

And the most remarkable process of all is reproduction. The science of physiology is largely the account of how the minutest details of our organization, for example, the amounts of dozens of different substances in the blood, are exactly regulated. Now in a self-regulating machine some details, such as steam pressure, or speed of revolution, are regulated, but most of the parts are solid, and have a form and size fixed once for all. This is not so in a living being. Even solid parts, such as bones, are in a continual state of flux. In a full grown man new materials are constantly being laid down in them, and are constantly removed. The steadiness of form in an animal is more like that of a flame or a waterfall than that of a house or a statue. As we analyse life, it seems to resolve itself into self-regulation with no permanent structures to act as regulators. We have got a long way from the idea of a machine.

The machine theory also breaks down when we consider our minds. The mind has a unity of its own. Somehow the most diverse elements, sensations, emotions, thought and will, are held together. And yet in spite of this unity the mind depends completely on th body. Cut

off the blood supply from parts of the brain and the most intelligent man becomes a hopeless idiot. An attack of lethargic encephalitis often turns a previously good child into a little criminal. Serious damage to the frontal lobes may paralyse initiative. An injury to other parts of the brain may wipe out special faculties, such as memory for places or words. The mind depends on the brain, but it has unity of a quite different kind to anything found in a machine.

Life, then, seems to be a synthesis of two opposites, mechanism and individuality. A man is a machine, and at the same time an individual. There is nothing really surprising in this. We find the same union of opposites everywhere. Wood is both hard and soft. If it were not hard, we could not use it for furniture. If it were not soft, we could not cut it. We can ask of any living thing how much is it a machine, and how much an individual? And the answers are very interesting. For we find that both in the life of the individual and in the evolution of races, there is generally, though not always, a progress from mechanism to individuality.

A plant is not much of an individual. You can cut a geranium or a potato in two, and both parts will grow. You can graft a rose on to a briar, or even a tomato on to a deadly nightshade. The lower animals are the same. You can graft two sea anemones together, or cut a flat-worm into several bits, all of which will live. You cannot do this with the higher animals when they are fully grown. So we can say that life is something between mechanism and individuality, but seems to strive towards greater individuality or oneness.

Even within a single living creature, life exists at several different levels. A tortoise's heart will stay alive

for months. This prompts us to ask the question, 'What is the smallest part of a living creature which still has life of its own?' If life is essentially organization there must be an answer to this question. If a man, animal, or plant were a complete individual, the separate parts could not have a life of their own.

Microscopical observation shows that both animals and plants are built up of cells, each surrounded by a membrane and composed of a kind of jelly, with a tougher body, the nucleus, in the middle. The size varies greatly, but an average human cell is about a thousandth of an inch across.

A single cell from a man or animal can live and multiply if given proper food. But if a cell is divided up, the parts will not live for any length of time. The technique of growing cells in tissue culture is one of the most remarkable of biological inventions.

Life in the higher animals and plants is organized at two levels. Each cell has a life of its own, and somehow or other all the cells co-operate in the life of the whole body. There are, of course, also simple animals and plants, mostly microscopic, which consist of single cells. But once in each life cycle, even of a higher animal or plant, life drops down, so to say, to the cellular level.

From the chemical point of view, then, each sort ot living substance is a particular pattern of chemical compounds. and each sort of life is a particular pattern of chemical change. The pattern of chemical change is very similar in related organisms like a man and a dog, not so similar in a man and a mushroom. Nevertheless the patterns and their details are astonishingly alike all through the realm of life.

The simplest pattern of chemical change familiar to us is a flame. A candle flame keeps a fairly steady shape and size. Different changes are occurring in the different parts of it. Its matter is always changing. It can give rise to other flames, and so on. Considered as a set of chemical reactions, a man is as much more complicated than a flame as grand opera is more complicated than a blast on a whistle. Nevertheless, the analogy is real. In particular a flame is like an animal in that you cannot stop it, examine the parts, and start it again, like a machine. Change is part of its very being. Even apparently unchanging living things like seeds are really undergoing slow change, and using oxygen. That is why seeds cannot be kept indefinitely. In spite of stories to the contrary, the wheat in Egyptian tombs has long used up its reserves of starch, and starved to death.

If we pursue the chemical description too far we are apt to forget the fundamental fact that life is a self-regulating pattern of chemical changes, just as living things are self-regulating machines.

Life is adaptive. We might almost say that it is adaptation. A plant grows so as to get light for its leaves and water for its roots. An animal seeks food or a mate. And every action of a part involves the co-operation of the other parts. The stem of the plant must grow strong enough to support the leaves. The muscles of the animal must be supplied with oxygen from the lungs or gills, sugar from the liver, and so on. All the main organs have functions. What is more the individual chemical reactions have functions.

Some people think that we should not speak of the function of the heart, but the purpose of the heart. I

believe that this would be misleading. Life is very efficient, but it is extraordinarily blind in the sence of being unable to adapt itself to novel circumstances, until, in the higher animals and man, it is illuminated by mind. It probably is as big a mistake to regard life as purposive as to think of it as merely mechanical. The heart is a very efficient pump, and well regulated under normal circumstances. But it will go on pumping blindly if taken out of the body and supplied with warm water containing suitable salts and a little oxygen. Most animals, even of a very simple kind, can learn by experience, and seem to have some rudiments of mind. Plants cannot do so. The rose must be pruned every year. It does not learn to make flowers instead of wood. And many parts of the higher animals, for example, the beards of men who shave daily, are just as obstinate as the rose.

It is time that we looked at some of the imperfections of life. For life is never perfectly adapted to its environment. Some organs have no function whatever. For example, the dandelion produces pollen. In most plants the pollen is essential for the fertilization of ovules which turn into seeds. No doubt this was so in the ancestors of the dandelion. But the dandelion has given up sexual reproduction, and its pollen is absolutely wasted. Man has plenty of useless organs. The toenails are quite useless, at least to civilized men, and occasionally troublesome. Among internal organs the vermiform appendix is equally useless and more dangerous. But both these organs, like the pollen of the dandelion, were useful to ancestral forms. Every animal and plant probably has useless organs of this kind, which have been of use in the past. But other organs are not only useless, but so for as we can see, have never been useful in the

past. Such are the lobe of the ear in man, and many fleshy out-growths of birds, such as the cock's comb.

Just as there are useless parts of the body, there are useless chemical reactions within it. Further, many adaptations are incomplete. The different parts of the eye are so badly adapted that most men need spectacles at one time or another. Finally, no adapations last for ever. All men, animals and plants die. Yet this imperfection, while it is an evil from the point of view of the individual, is absolutely essential to life as a whole. Without imperfection there would be no evolution, as Darwin was the first to see.

There is a sense in which all life is one. Although life is manifested in countless millions of individuals (a single pound of soil may contain a million million bacteria) and though these individuals devour one another without mercy, it is not meaningless to speak of the unity of life. Thanks to the labours of palaeontologists who study fossils, and comparative anatomists who compare different forms, we can trace back the ancestry of the various kinds of plant and animal alive today.

The fossil record does not tell us of the common ancestors of vertebrates (such as the animals so far mentioned), insects, molluscs, and sea urchins. But their early development and the structure of their cells is so similar that almost all biologists believe in their relationship. Finally, it is believed that even animals and plants were descended from common ancestors. When we go below the superficial characters the resemblances are overwhelming. Thus the laws of heredity discovered by Mendel in peas are found to hold without any modification for most human characters. The chemical reactions which take place when yeast makes alcohol from sugar

gave the clue to those which provide the energy when a human muscle contracts.

Evolution may happen in several ways. A single favourable variation may spread through a species. A favourable combination of variations may be isolated in a particular area. Or a change in climate, food, or enemies may make a previously useless variation useful. A special type of variation, which is not uncommon in plants, makes the new race infertile with the ancestral form, and thus a new species arises.

But three conditions are necessary for evolution. A race must not be perfectly adapted to its environment, but must vary round the most perfectly adapted type. Individuals must die, to make room for fresh experiments of nature. And there must be an overproduction of individuals, so that the least fit are weeded out by natural selection. All these conditions are evil from the point of view of the individual, good from that of the evolving species.

But just as most individuals are failures in the evolutionary struggle and leave no descendants, so are most species. Evolution generally ends in highly successful species with no future. The horse is too specialized to evolve into anything else. He has lost all but one of his toes and many of his teeth. He could never evolve into a climber, a swimmer, or a flier. The great steps in evolution have generally been made by relatively unspecialized animals.

As the result of evolution every animal and plant is a piece of embodied history. It contains many vestiges of the past which have outlived their use, and a few untried variations, which may be, but probably will not be, the

basis of further evolutionary changes. It is at once an anachronism and an experiment.

We see then that life is an extraordinary bundle of contradictions. It is something between mechanism and individuality, between chance and purpose, between happy but stagnant perfection and struggling but evolving imperfection. It is a process of continual change, yet embodied in very characteristic forms. It is a constant struggle against death, yet without death it could not progress.

The philosopher tries to define it, but no definition will cover its infinite and self-contradictory variety. The biologist studies it, well aware that he can never hope to fathom its full complexity. But every step forward in our knowledge of it brings it more under our control. Biology has already revolutionized agriculture and medicine. As man learns about human biology, he will gradually come to apply reason in place of emotion and tradition in regulating his own life.

Knowledge for the sake of knowledge is indeed a great ideal, but it needs to be supplemented by the newer ideal that all knowledge is for the service of man.

Science and art belong to the whole world and the barriers of nationality vanish before them.

Goethe

He who knows a WHY of living surmounts almost every HOW

Nietzsche

Religion, Philosophy, and Science

JAWAHARLAL NEHRU

India must break with much of her past and not allow it to dominate the present. Our lives are encumbered with the dead wood of this past ; all that is dead and has served its purpose has to go. But that does not mean a break with, or a forgetting of, the vital and life-giving in that past. We can never forget the ideals that have moved our race, the dreams of the Indian people through the ages, the wisdom of the ancients, the buoyant energy and love of life and nature of our forefathers, their spirt of curiosity and mental adventure, the daring of their thought, their splendid achievements in literature, art and culture, their love of truth and beauty and freedom, the basic values that they set up, their understanding of life's mysterious ways, their toleration of ways other than theirs, their capacity to absorb other peoples and their cultural accomplishments, to synthesize them and dovelop a varied and mixed culture ; nor can we forget the myriad experiences which have built up our ancient race and lie embedded in our subconscious minds. We will never forget them or cease to take pride in that noble heritage of ours.

If India forgets them she will no longer remain India and much that has made her our joy and pride will cease to be.

It is not this that we have to break with, but all the dust and dirt of ages that have covered her up and hidden her inner beauty and significance, the excrescence and abortions that have twisted and petrified her spirit, set it in rigid frames, and stunted her growth. We have to cut away these excrescences and remember afresh the core of that ancient wisdom and adapt it to our present circumstances. We have to get out of traditional ways of thought and living which, for all the good they may have done in a past age, and there was much good in them, have ceased to have significance to-day. We have to make our own all the achievements of the human race and join up with others in the exciting adventure of man, more exciting to-day perhaps than in earlier ages, realising that the has ceased to be governed by national boundaries or old divisions and is common to the race of man everywhere. We have to revive the passion for truth and beauty and freedom which gives meaning to life, and develop afresh that dynamic outlook and spirit of adventure which distinguished those of our race who, in ages past, built our house on these strong and enduring foundations. Old as we are, with memories stretching back to the early dawns of human history and endeavour, we have to grow young again, in tune with our present time, with the irrepressible spirit and joy of youth in the present and its faith in the future.

Truth as ultimate reality, if such there is, must be eternal, imperishable, unchanging. But that infinite, eternal and unchanging truth cannot be apprehended in its fullness by the finite mind of man which can only grasp,

at most, some small aspect of it limited by time and space, and by the state of development of that mind that the prevailing ideology of the period. As the mind develops and enlarges its scope, as ideologies change and new symbols are used to express that truth, new aspects of it come to light, though the core of it may yet be the same. And so, truth has ever to be sought and renewed, reshaped, and developed, so that, as understood by man, it might keep in line with the growth of his thought and the development of human life. Only then does it become a living truth for humanity, supplying the essential need for which it craves, and offering guidance in the present and for the future.

But if some one aspect of the truth has becn petrified by dogma in a past age, it ceases to grow and develop and adapt itself to the changing needs of humanity ; other aspects of it remain hidden and it fails to answer the urgent questions of a succeeding age. It is no longer dynamic but static, no longer a life-giving impulse but dead thought and ceremonial and a hindrance to the growth of the mind and of humanity. Indeed, it is probably not even understood to the extent it was understood in that past age when itgrew up and was clothed in the language and symbols of that age. For its context is different in a later age, the mental climate has changed, new social habits and cusetoms have grown up, and it is often difficult to understand the sense much less the spirit, of that ancient writing. Moreover, as Aurobindo Ghose has pointed out, every truth, however true in itself, yat taken apart from others which at once limit and complete it, becomes a snare to bind the intellect and a misleading dogma ; for in reality each is one thread of a complex weft and no thread must be taken apart from the weft.

Religions have helped greatly in the development of humanity. They have laid down values and standards and have pointed out principles for the guidance of human life. But with all the good they have done, they have also tried to imprison truth in set forms and dogmas, and encouraged ceremonials and practices which soon lose all their original meaning and become mere routine. While impressing upon man the awe and mystery of the unknown that surrounds him on all sides, they have discouraged him from trying to understand not only the unknown but what might come in the way of social effort. Instead of encouraging curiosity and thought, they have preached a philosophy of submission to nature, to established churches, to the prevailing social order, and to everything that is. The belief in a supernatural agency which ordains everything has led to a certain irresponsibility on the social plane, and emotion and sentimentality have taken the place of reasoned thought and inquiry. Religion, though it has undoubtedly brought comfort to innumerable human beings and stabilized society by its values, has checked the tendency to change and progress inherent in human society.

Philosophy has avoided many of these pitfalls and encouraged thought and inquiry. But it has usually lived in its ivory tower cut off from life and its day-to-day problems, concentrating on ultimate purpose and failing to link them with the life of man. Logic and reason were its guides and they took it far in many directions, but that logic was too much the product of the mind and unconcerned with fact.

Science ignored the ultimate purposes and looked at fact alone. It made the world jump forward with a leap, built up a glittering civilization, opened up innumerable

avenues for the growth of knowledge, and added to the power of man to such an extent that for the first time it was possible to conceive that man could triumph over and shape his physical environment. Man became almost a geological force, changing the face of the planet earth chemically, physically, and in many other ways. Yet when this sorry scheme of things entirely seemed to be in his grasp, to mould it nearer to the heart's desire, there was some essential lack and some vital element was missing. There was no knowledge of ultimate purposes and not even an understanding of the immediate purpose, for science had told us nothing about any purpose in life. Nor did man, so powerful in his control of nature, have the power to control himself, and the monster he had created ran amok. Perhaps new developments in biology, psychology, and similar sciences, and the interpretation of biology and physics, may help man to understand and control himself more than he has done in the past Or, before any such advances influence human life sufficiently, man may destroy the civilization he has built and have to start anew.

There is no visible limit to the advance of science, if it is given the chance to advance. Yet it may be that the scientific method of observation is not always applicable to all the varieties of human experience and cannot cross the uncharted ocean that surrounds us. With the help of philosophy it may go a little further and venture even on these high seas. And when both science and philosophy fail us, we shall have to rely on such other powers of apprehension as we may possess. For there appears to be a definite stopping place beyond which reason, as the mind is at present constituted, cannot go.

Realizing these limitations of reason and scientific method, we have still to hold on to them with all our

trength, for without that firm basis and background we can have no grip on any kind of truth or reality. It is better to understand a part of truth and apply it to our lives, than to understand nothing at all and flounder helplessly in a vain attempt to pierce the mystery of existence. The applications of science are inevitable and unavoidable for all countries and peoples to-day. But something more than its application is necessary. It is the scientific approach, the adventurous and yet critical temper of science, the search for truth and new knowledge, the refusal to accept anything without testing and trial, the capacity to change previous conclusions in the face of new evidence, the reliance on observed fact and not on preconceived theory, the hard discipline of the mind – all this is necessary, not merely for the application of science but for life itself and the solution of its many problems. Too many scientists to-day, who swear by science, forget all about it outside their particular spheres. The scientific approach and temper are, or should be, a way of life, a process of thinking, a method of acting and associating with our fellowmen. That is a large order and undoubtedly very few of us, if any at all, can function in this way with even partial success. But this criticism applies in equal or even greater measure to all the injunctions which philosophy and religion have laid upon us. The scientific temper points out the way along which man should travel. It is the temper of a free man. We live in a scientific age, so we are told, but there is little evidence of this temper in the people anywhere or even in their leaders.

Science deals with the domain of positive knowledge but the temper which it should produce goes beyond that domain. The ultimate purposes of man may be said to be to gain knowledge, to realize truth, to appreciate goodness

and beauty. The scientific method of objective inquiry is not applicable to all these, and much that is vital in life seems to lie beyond its scope – the sensitiveness to art and poetry, the emotion that beauty produces, the inne recognition of goodness. The botanist and zoologist may never experience the charm and beauty of nature; the sociologist may be wholly lacking in love for humanity. But even when we go to the regions beyond the reach of the scientific method and visit the mountain tops where philosophy dwells and high emotions fill us, or gaze at the immensity beyond, that approach and temper are still necessary.

Very different is the method of religion. Concerned as it is principally with the regions beyond the reach of objective inquiry, it relies on emotion and intuition. And then it applies this method to everything in life, even to those things which are capable of intellectual inquiry and observation. Organized religion, allying itself to theology and often more concerned with its vested interests than with things of the spirit, encourages a temper which is the very opposite to that of science. It produces narrowness and intolerance, credulity and superstition, emotionalism and irrationalism. It tends to close and limit the mind of man, and to produce a temper of a dependent, unfree person.

Even if God did not exist, it would be necessary to invent Him. Perhaps that is true, and indeed the mind of man has always been trying to fashion some such mental image or conception which grew with the mind's growth. But there is something also in the reverse proposition: even if God exists, it may be desirable not to look up to Him or to rely upon Him. Too much dependence on supernatural factors

may lead and has often led, to a loss of self-reliance in man and to a blunting of his capacity and creative ability And yet some faith seems necessary in things of the spirit which are beyond the scope of our physical world, some reliance on moral, spiritual, and idealistic conceptions, or else we have no anchorage, no objectives or purpose in life. Whether we believe in God or not, it is impossible not to believe in something, whether we call it a creative life-giving force or vital energy inherent in matter which gives it its capacity for self-movement and change and growth, or by some other name, something that is as real, though elusive, as life is real when contrasted with death. Whether we are conscious of it or not, most of us worship at the invisible altar of some unknown god and offer sacrifices to it–some ideal, personal, national or international; some distant objective that draws us on, though reason itself may find little substance in it; some vague conception of a perfect man and a better world. Perfection may be impossible of attainment, but the demon in us, some vital force, urges us on and we tread that path from generation to generation.

As knowledge advances, the domain of religion, in the narrow sense of the word, shrinks. The more we understand life and nature, the less we look for supernatural causes. Whatever we can understand and control ceases to be a mystery. The processes of agriculture, the food we eat, the clothes we wear, our social relations, were all at one time under the dominion of religion and its high priests. Gradually they have passed out of its control and become subjects for scientific study. Yet much of this is still powerfully affected by religious beliefs and the superstitions that accompany them. The final mysteries still remain far beyond the reach of the human mind and

are likely to continue to remain so. But so many of life's mysteries are capable of and await solution, that an obesssion with the final mystery seems hardly necessary or justified. Life still offers not only the loveliness of the world but also the exciting adventure of fresh and never ceasing discoveries of new panoramas opening out and new ways of living, adding to its fulness and ever making it richer and more complete.

It is therefore with the temper and approach of scienc, allied to philosophy, and with reverence for all that lies beyond, that we must face life. Thus we may develop an integral vision of life which embraces in its wide scope the past and the present, with all their heights and depths and look with serenity towards the future. The depths, are there and cannot be ignored, and always by the side of the loveliness that surrounds us is the misery of the world. Man's journey through life is an odd mixture of joy and sorrow; thus only can he learn and advance. The travail of the soul is a tragic and lonely business. External events and their consequences affect us powerfully, and yet the greatest shocks come to our minds through inner fears and conflicts. While we advance on the external plane, as we must if we are to survive, we have also to win peace with ourselves and between ourselves and our environment, a peace which brings satisfaction not only to our physical and material needs but also to those inner imaginative urges and adventurous spirits that have distinguished man ever since he started on his troubled journey in the realms of thought and action. Whether that journey has any ultimate purpose or not we do not know, but it has its compensations, and it points to many a nearer objective which appears attainable and which may again become the starting point for a fresh advance.

Science has dominated the western world and every one there pays tribute to it, and yet the west is still far from having developed the real temper of science. It has still to bring the spirit and the flesh into creative harmony. In India in many obvious ways we have a greater distance to travel. And yet there may be fewer major obstructions on our way, for the essential basis of Indian thought for ages past, though not its later manifestations, fits in with the scientific temper and approach, as well as with internationalism. It is based on a fearless search for truth, on the solidarity of man, even on the divinity of everything living, and on the free and oo-operative development of the individual and the species, ever to greater freedom and higher stages of human growth.

The border between imaginative play and art in general, poetic vision and science, is not as sharp as many people believe. They all are ways to the joy of life and many bridges bring them together.

Richard M. Field

Most of the basic problems of mankind are of a biological nature : overproduction and underproduction, foodstuffs and organic raw-materials, overpopulation and underpopulation, economic prosperity and depression, mass-apathy and mass-emotion, and finally war and peace are fundamentally biological problems. As soon as this will be understood and as soon as the leading statesmen will be willing to contemplate it on this scientific level, in cooperation with such an objective scientific Institution representing all branches of science, we shall have found the way to the highest art of living.

Hugo Boyko

Scientific Outlook

C. V. RAMAN

Science and Progress

We live in an era of scientific progress and it is a very gratifying feature that India is beginning to pull its weight in this respect. Modern scientific progress shows side by side two apparently contradictory features. On the one hand, we have an enormous accumulation of raw scientific material, the significance of which, in many cases, is hardly apparent except to specialists in very limited fields of investigation. On the other hand, we have a great process of scientific synthesis going on tending towards the simplification and unification of the fundamental principles of natural knowledge in all its ramifications. It should never be over-looked that science is in reality a great impartiable estate and that the boundaries drawn across it to divide it into restricted fields are in essence artificial. I think the history of science has shown over and over again that it is only by boldly cutting across these artificial boundaries that progress of real significance can be achieved.

The principal requisite for success in scientific research is not the maturity of knowledge associated with age and experience but the freshness of outlook which is the natural attribute of youth.

The principal function of the order generation of scientific men is to discover talent and genius in the younger generation and to provide ample opportunities for its free expression and expansion.

Inner urge

Science can only flower out when there is an internal urge. It cannot thrive under external pressures. I strongly believe that the fundamental science cannot be driven by instructional, industrial, Governmental or military pressures.

While specialisation is necessary, an excessive narrow outlook defeats the primary purpose of science which is to advance our essential comprehension of nature as a whole.

Let us watch that at least the brother-hood of inquiry does not fall victim to the monster Politics, even though the BIGS do not set a shining example.

Intellectual beauty is indeed the highest kind of beauty. Science is the fusion of man's aesthetic and intellectual functions devoted to the representation of Nature. It is therefore the highest form of creative art.

Scientific discovery

The reception given at first to even capital discoveries by the outer world is not always one of respectful admiration for the achievement of the discoveries. One of the

commonest ways in which the achievement is sought to be minimised by the unthinking or the envious is by attributing it to accident or a stroke of luck akin to the winning of a lottery ticket. Such comments are, of course, deplorable and indeed quite meaningless. The idea that a scientific discovery can be made by accident is ruled out by the fact that the accident, if it is one, never occurs except to the right man. The happy discoverer in science is invariably a seeker after knowledge and truth working in a chosen field of his own and inspired in his labours by the hope of finding at least a little grain of something new. The commentators who like to consider discoveries as accidents forget that the most important part of a scientific discovery is the recognition of its true nature by the observer, and this is scarcely possible if he does not possess the requisite capacity or knowledge of the subject. Rarely indeed are any scientific discoveries made except as the result of a carefully thought-out programme of work. They come, if they do come, as the reward of months or years of systematic study and research in a particular branch of knowledge.

"The miracle of Science is at our disposal to use or abuse, to make or to mar. With science we may lay civilization in ruins or enter into a period of plenty and well being the like of which has never been experienced by mankind."

H. A. L. Fischer

Civilization and Atomic Energy

HOMI BHABHA

Knowledge is perhaps the most important possession of Man. It is the accumulated knowledge of centuries which differentiates modern Man from his ancestor in the dawn of civilization. It is this knowledge, and not any notable change in his physical and mental equipment, which has enabled him to build the civilization of today.

In a broad view of human history it is possible to discern three great epochs. The first is marked by the emergence of the early civilizations in the valleys of the Euphrates, the Indus, and the Nile, the second by the Industrial Revolution, leading to the civilization in which we live, and the third by the discovery of atomic energy and the dawn of the Atomic Age. Each epoch marks a change in the energy pattern of society.

In a practical sense, energy is the great prime mover, which makes possible the multitude of actions on which our daily life depends. Indeed, it makes possible life itself.

It may be remarked in passing that by far our greatest source of energy is the sun. It is this solar energy, received as light and heat, which has produced those physical conditions on the surface of the earth which are necessary for the emergence and continuance of life. It is well known that atomic energy is the ultimate source of this vast output of radiant energy from the sun. But although life depends on solar energy for its existence, man has made very little progress since time immemorial in the conscious use of this vast source of energy.

The First Epoch

Man has existed on this earth for well over 250,000 years. And yet the earliest civilizations of which we have record only date back some 8,000 years. It took man several hundred thousand years to acquire those skills and techniques on which the early civilizations were based, the techniques of agriculture, animal husbandry, weaving, pottery, brick making and metallurgy. The acquisition of these techniques and the emergence of the early civilizations must be regarded as the first great epoch in human history.

Despite many differences in habit, culture and social pattern, all these early civilizations were built essentially on the same foundation. All the energy for doing mechanical work, for tilling the ground, for drawing water, for carrying loads, and for locomotion was supplied by muscle, whether human or animal. Molecular or chemical energy, as for example that obtained by burning wood, was only used to a limited extent for cooking and heating, and in a few technical processes, as in metallurgy.

It is important to note the severe limitations that this restricted supply of energy put on the development of

civilization. A man in the course of heavy physical labour in an eight-hour day can hardly turn out more than half a kilowatt-hour of useful work. This is not much more than is necessary to maintain him at a bare subsistence level. It is to be compared with the rough figure of 20 kilowatt-hours or more of energy per person which is daily utilized in the industrially advanced countries today. It followed that a high level of physical comfort and culture could only be enjoyed by a small fraction of the population by making use of the collected surplus labour of the rest. It is sometimes forgotten that all the ancient civilizations were carried on the muscle power of slaves or of a particular class in society. Through the very limitations of the available energy, the fruits of civilization could only be enjoyed by a few.

The Second Epoch

A departure from this basic pattern only began with the scientific and technical developments of the 17th and 18th centuries, as a result of which man began to make increasing use of chemical energy for doing and augmenting the mechanical work which had till then been done by muscle. The widespread use of chemical energy, especially that obtained by burning the fossil fuels, coal and oil, marks the second great epoch in human history. It led to the Industrial Revolution, and the industrialized pattern of society and civilization, which is typical of this age. In one highly industrialized country today 23 kilowatt-hours of energy are utilized daily per head, corresponding to the muscular effort of 45 slaves. In another advanced country the figure is about twice this. This shows how radically the energy pattern of a modern industrialized society differs from that of the early civilizations and of a non-industrialized society.

The total consumption of energy in the world has gone up in a staggering manner. It is convenient in dealing with such enormous amounts of energy to use an appropriately large unit, denoted by Q, which is equal to a million million million British thermal units of energy, corresponding to the combustion of some 33,000 million tonnes of coal. It is estimated that in the $18\frac{1}{2}$ centuries after Christ some 9Q of energy were consumed, corresponding to an average rate of under half-a-Q per century. But the actual rate in 1850 was probably about 1Q per century. The rate continued to increase, and it appears that by 1950 roughly another 5Q may have been consumed, while the rate had then risen to 10Q per century.

The population of the world has been increasing rapidly. It is estimated that it was a few hundred million in 1 A.D. It may have been less than three hundred million. There appears to have been no remarkable increase till about the middle of the 17th century. Thereafter, for a reason which we do not understand, the population appears to have increased rapidly. It is estimated to have reached 1,500 million in 1900, some 2,000 million in 1930, and roughly 2,300 million in 1950. We will have to estimate what the world population will be in 1975 and in A.D. 2000.

Next we have to determine the future per capita utilization of energy to which I have already alluded. It is estimated that the per capita utilization of energy has been increasing in the world as a whole during the last 90 years at some 2.2 per cent per annum compounded, while the present rate is about 3 per cent. For some highly industrialized countries the rate of increase has been as high as 4 per cent and more. What will the rate be as the

underdeveloped areas of the world, with their argel populations, become industrialized, with all the advantages of modern technology at their disposal, and the experience of others to learn from? What is the average per capita utilization of energy which we must anticipate in A. D. 2000?

There is a point which must be remembered in this context. Industrialization has so far proceeded on the basis that most of the materials needed for it are available on demand. This may no longer be so. It is estimated that the known reserves of a number of metals used in industry will not last more than a few decades at their present rate of consumption. The industrialization of large new areas of the world will aggravate the situation still further, and we will be forced to use natural or synthetic substitutes. This will make additional demands for energy beyond those we can anticipate on the present basis.

Of the enormous consumption of energy in the world today about 80 per cent is provided by the combustion of coal, oil and gas, while hydro-electric power provides less than about $1\frac{1}{2}$ per cent. The contribution of muscular energy is estimated to be about 1 per cent. The rest, amounting to something over 15 per cent is obtained by burning wood and agricultural waste. Hydro-electric power is never likely to contribute more than a small fraction of the total energy consumption of the world, since the total potential capacity is relatively limited. Nor is the contribution from wood and agricultural waste likely to increase substantially. Hence, as the total demand for energy increases, a larger and larger fraction will have to be provided by the fossil fuels, coal and oil, unless some entirely new source of energy is found.

It is, there fore, of importance for us to have fairl accurate estimates of the reserves of coal and oil that remain in the ground. We are not concerned here with the absolute amounts of these substances in the earth's crust, but with the amounts that are recoverable at a cost not many times higher than present costs. The consensus of opinion seems to be that the total economically recoverable world reserves of coal, oil, gas and oil shale are equivalent in energy value to under 100 Q. Some have put the figure under 40Q. It is probable that, at the rate at which the world consumption of energy is increasing, these reserves will be exhausted in under a century.

Let us pause to see what this means. The bulk of our coal, the bituminous coal, comes from the Carboniferous Age, some 250 million years ago. We are exhausting these reserves, which have been built up by nature over long periods of time, in a few centuries, in a flash of geological time.

Certain important conclusions can be reached without answering in detail the difficult questions which I have just touched on. Of the total world consumption of energy, amounting to 1Q per decade in 1950, 37 per cent was in the United States. If the entire present population of the world were to consume energy per capita at the same rate as in the United States, the total consumption of energy in the world would be over $5\frac{1}{2}$Q per decade instead of the present 1Q. Coupled with a doubling of the world's population within the next hundred years, which is the least that we can expect, this would exhaust the known reserves of fossil fuels in under a century. In this simple arithmetic no allowance has been made for the fact that the standard of living of the industrially

advanced countries is rising, and, we hope, will continue to rise.

This conclusion is of great significance. It shows that our presently known reserves of coal and oil are insufficient to enable the underdeveloped countries of the world, which contain a major part of its population, to attain and maintain for long a standard of living equal to that of the industrially most advanced countries. It shows the absolute necessity of finding some new source of energy, if the light of our civilization is not to be extinguished, because we have burnt out our fuel reserves.

The Third Epoch

It is in this context that we turn to atomic energy for a solution. It has been estimated that the total recoverable world reserves of uranium and thorium contain an amount of energy of the order of 1700Q. If this is really so, then atomic energy could, first, provide the energy necessary to enable the underdeveloped countries to reach the standard of living of the industrialized countries, and secondly, enable the entire world to maintain a constantly rising standard of living for very many decades, and possibly for several centuries. For the full industrialization of the under-developed countries, for the continuation of our civilization and its further development, atomic energy is not merely an aid, it is an absolute necessity. The acquisition by man of the knowledge of how to release and use atomic energy must be recognized as the third great epoch in human history.

The basic ideas of atomic energy are simple, but its technology is sophisticated and difficult. Hundreds of tonnes of special materials have had to be produced in

states of extreme purity surpassing anything known hitherto even in the pharmaceutical industry. Highly radioactive substances have had to be treated chemically in bulk by remote control. All this has required the development of new methods and techniques at great expense and by enormous effort.

The immense concentration of atomic energy has made possible other developments whose immediate results have been less happy, and which have placed a pall of fear over the peoples of the world. I refer, of course, to the development of atomic and hydrogen bombs. The powerful and technically advanced nations have suffered most from this fear. The rise of an atomic power industry in many parts of the world, the development of which is necessitated by the growing demands for energy, will put into the hands of many nations quantities of fissile material, from which the making of atomic bombs will be but a relatively easy step.

Before he died Einstein put his signature to a document in which it was pointed out :"the best authorities are unanimous in saying that a war with H-bombs might quite possibly put an end to the human race. It is feared that if many H-bombs are used, there would be universal death – sudden only for a minority, but for the majority a slow torture of disease and disintegration."

The historical period we are just entering, in which atomic energy released by the fission process will supply some of the power requirements of the world, may well be regarded one day as the primitive period of the Atomic Age. It is well known that atomic energy can also be obtained by a fusion process, as in the H-bomb, and there is no basic scientific knowledge in our possession

today to show that it is impossible for us to obtain this energy from the fusion process in a controlled manner. The technical problems are formidable, but one should remember that it is not yet 35 years since atomic energy was released in an atomic pile for the first time by Fermi. I venture to predict that a method will be found for liberating fusion energy in a controlled manner within the next two decades. When that happens, the energy problems of the world will truly have been solved for ever, for the fuel will be as plentiful as the heavy hydrogen in the oceans.

All the basic discoveries upon which atomic energy is based were made before the Second World War by scientists of many nations working in free and full collaboration. The war put an end to this free exchange of knowledge, and most of the technical developments concerning atomic energy were made subsequently by a few nations, each working in isolation behind a wall of secrecy. It is to be hoped that through the remarkable improvement in the political climate which has taken place recently, and which we hope will continue, the barriers which remain will gradually disappear altogether. If so much has been achieved through the individual and isolated efforts of a few countries, how much more could be achieved by the combined effort of all. We have the unique opportunity of giving of our knowledge to others for the common good. Let us help the progress of mankind towards the ever-widening dawn of the Atomic Age, with the promise of a life, fuller and happier than anything we can visualize today.

Moral Aspects of Science

B. C. ROY

Science has been defined as an ordered knowledge of natural phenomena and of their inter-relation. Such knowledge has accumulated through centuries by observation of facts, by a correct deduction from such observation and formulation of theories to explain them, by confirmatory experiments to test the theories; any theory which would stand the trial of experiments would become part of scientific truth and knowledge. Such knowledge and such truth were originally used to implement nature, to increase the comforts and security of men. Even among primitive men, such knowledge and observation led to a conception of primitive religion, to a conception that natural phenomena are due to direct and immediate intervention of "Unseen Beings". How then can such a conception of science and its processes corrupt our morals? Or have we fallen off from this original conception of our ancestors and have adopted lower standard of values ?

The word "morals" is concerned with values, estimates of the ultimate problems of human conduct and what such conduct ought to be. The ultimate aim of

"morals" is to secure the "highest good" to distinguish between good and evil, to find out if the motives of human action and endeavour are being applied to attain this highest good, this, *summum bonum.* If it be the object of science, as it originally was "to increase the comforts and security of men" then science, as originally conceived and developed, cannot "corrupt our morals". If nature's gifts have been developed and perfected by man not for any higher purposes but to enable him to indulge in a blind orgy of destruction and devastation, the blame cannot be laid at the door of science or scientists. The sharp weapon, the knife of the surgeon was forged not to destroy the life of the individual but that the scientist might use it to save the sufferer from the ravages of a malignant affection; the gunpowder was manufactured not to kill thousands of innocent lives but to blast hillside to provide a channel of pure drinking water to the thirsty people on the other side of the hill and to provide thoroughfare for the masses; the investigations into the properties of phosphorous were directed not to incorporate it in the preparation of bombs to start conflagration in a market place where the poor live but to provide suitable and ready materials for getting light. Thus it is, that man at the dictate of his animal passion is out to prostitute science and the truths available to science, and thus to suppress and strangle "Truth". Science has taught that destruction and construction must go together. You cannot destory unless you are ready to construct. Even so in our human body, destruction of tissue cells are going on every moment of our life to be replaced by new cells and new tissues; if not, a void would be left. If a mad man chooses to utilize scientific knowledge only to destroy and not to construct, he only suppresses the scientific truth and lowers the moral value

of things. Einstein said in one place, "The present troubles of the world are due to science having advanced faster than morality; when morality catches up with science, these troubles would end". Sir Sarvapalli Radhakrishnan expressed a similar sentiment when he said that our aim should be to insist on the high mission of science and relate it organically to the central purpose of human life and society, to reconcile religious wisdom with scientific achievements.

Science is not confined to laboratories, its truths are to be found in a wider field of human endeavour; social and theological sciences require equal attention from the searchers after truth. For after all, is it not a fact that science, in spite of its apparent sub-divisions, is in truth one; we may, for the convenience of study and research, separate agricultural science from Geology and Botany; but can we look upon them as isolated and distinct one from the other? Should you not rather consider "the effects of science on the well-being of the community and the effects of social conditions on the Advance of Science?" If this proposition is accepted and acted upon, science and morality will develop together and we shall emerge into a new world order when Truth and Good will reign supreme.

The more we come to appreciate the latest developments in science and their application to human welfare, the more we begin to realise that while material resources are no doubt a fundamental requirement for the successful development of the country, we depend no less upon human resources. Moreover, it is not merely the technical knowledge, which one may possess that will help in his task, it is equally essential that there must be developed ability to apply this knowledge to the organisation and

development of industries and to the production of means of human welfare. There is moreover the need for adaptation. We might get technical knowledge from other more advanced countries, but the scientists of India should be able to adapt this technical knowledge to the needs of the country, so that it may be effectively operative under different climatic and environmental conditions and for utilisation of indigenous raw materials. It is, therefore, not enough to borrow from other countries the results of their researches; we should be able to undertake original researches ourselves and adapt the results of such researches to the conditions obtaining in our own country. Such researches would be a continuous, and, no doubt, an arduous process too. Without it no progress can be achieved in this competitive world.

Human mind ordinarily follows a particular groove and does not easily adapt itself to new ideas. Scientists would indeed be doing a great service to society if they would demonstrate to the common man the value of quickly adapting and utilising the results of new researches.

It is science which has been the cementing agency between peoples of different races, religious traditions and customs. When a whole population uses a common railway system, and telegraph and telephone links, or listens to music and speeches radiating from a common broadcasting station, or thrills at the same cinematographic film projected at a thousand theatres simultaneously, or rides to and from work in common carriers like omnibuses and tramcars, or wears standardised garments and shoes, there results a sense of unity. Then science becomes an agency that draws millions of people into one common fabric of human society or social order.

Swami Vivekananda's Synthesis of Science and Religion

SWAMI RANGANATHANANDA

The subjects of science and religion are getting more and more important to man in the modern age. They are two great disciplines, which, when combined harmoniously, can bring about an all-round expression of human genius. But, unfortunately, for the last few centuries, the relationship between the two has not been quite happy. In the twentieth century, however, a new approach is becoming evident, and the representative thinkers among scientists and religious people are beginning to discern a close interrelation between these two branches of human knowledge. They are slowly veering round to the point of view that science and religion can heartily embrace each other without detriment to the cause for which each stands, and work for the good of humanity. It is being realized more and more by both that there are elements in science that religion can adopt in order to fortify itself, and elements in religion that can deepen and strengthen science. I shall here touch upon some of these points of contact, and

discuss the methods and results of both the disciplines, against the background of the unity and totality of knowledge, and in the light of the synthetic approach and vision of Swami Vivekananda, who was an outstanding spiritual and intellectual luminary of the modern age and who worked successfully to bring about this great consummation. Writes Romain Rolland about him :

> 'In the two words equilibrium and synthesis, Vivekananda's constructive genius may be summed up. He embraced all the paths of the spirit : the four *yogas* in their entirety, renunciation and service, art and science, religion and action, from the most spiritual to the most practical. . . . He was the personification of the harmony of all human energy.'

The Scientific Discipline

The civilization in which we live today is the product of the discipline of the human mind known as science. When we study science at close quarters, in the way the great scientists have applied themselves to this pursuit, we find two aspects in its discipline. The first is *pure science*, science which tries earnestly to understand the truth of experience through a dispassionate inquiry ; and the second is *applied science*, in which the truths discovered by pure science flow as inventions for the technical enrichment of human life. These two, science as *lucifera* and science as *fructifera*, science as *light* and science as *fruit*, always go together. Knowledge leads to power, and power leads to control and manipulation of the forces of nature, enabling man to condition his life and environment with deliberation. Every new discovery in pure science, at some stage or other, becomes converted into applied science, into control and manipulation of the forces of nature. And the result, as revealed in recent history, is the great saga of scientific discovery and invention

resulting in the world-wide technological civilization of today. It is a most fascinating study how the human mind, disciplined in this pursuit of science, develops the capacity to wrest from nature truth after truth, hidden and jealously guarded by her, leading to our extraordinary age of nuclear science and space travel.

Limitations of Science

But, when we go deeper into this subject of science, its limitations become apparent. To illustrate: two branches of science, *viz*, physics, including astronomy, and biology, have given us a vast body of insights regarding the nature of the universe and man. Up to the end of the nineteenth century, physics was warped in its final judgements. It saw materialism and mechanism reigning supreme in the universe. There was then a cock-sureness in its pronouncements; but, in the twentieth century, an element of humility is discernible in the attitude of the great physicists of the age. In the nineteenth century, knowledge was not deep enough, and scientists looked only at the surface of things. But, along with the discovery of such facts as radio-activity and insight into the nucleus of the atom, the realization has come that there is a severe limitation placed on our knowledge regarding the truth of the external world. Science owns today that it deals only with the *appearance* of things and not with the *reality* behind these appearances. Some of the greatest of modern physicists tell us that what science has revealed of the world around us is only the outer aspect of things. Behind this *observable* universe, there is an *unobservable* universe. This is a great confession of the limitations of science and its methods. Science is dealing with phenomena revealed by the senses or by apparatuses helpful to the senses. But

these senses reveal so little, and what they reveal only tells us that there are realities behind the sense world determining it and controlling it. Science restricts itself to the understanding of the observable part of the universe and to controlling its energies for the uses of man.

A similar situation obtains in the science of biology. In the last century, it was cock-sure about its pronouncements. By a study of the different aspects of the phenomena of life it arrived at the great theory of evolution, from which it drew certain conclusions which directly led to a form of materialism that equated man with the animal, and both to a machine. Today, scientists tell us that they were not happy titles that Darwin chose for his famous books *The Origin of Species* and *The Descent of Man*. Sir Julian Huxley suggests that these could have been more appropriately titled *The Evolution of Organisms* and *The Ascent of Man*. But then, these books appeared at a time when a fierce controversy was going on between emerging science and the entrenched Christian dogma, and this had its impact even on the choosing of the titles of great scientific books. The science of physics with its thoroughgoing materialism and mechanistic determinism, and the science of biology with its newly discovered evolutionary theory and its domination by the general materialistic outlook of science and scientists of the age, helped to shatter nineteenth century man's faith in religion and spiritual values.

Limitations of dogma-bound Religion

Added to this was the attack on religion from the great social idealists and revolutionary social thinkers like Karl Marx It was the period of the industrial revolution. These idealists asked : If God is there in an extra-cosmic heaven, why is there so much suffering in this world, why

are millions starving, and why are thousands of little children made to slave in factories and workshops for the gain of a few capitalist exploiters ? This kind of inequality, this kind of oppression of man by man in the presence of an all-powerful God, is something we cannot understand or bear. Marx, accordingly, characterized religion as the 'soul of soulless conditions, the heart of a heartless world, the opium of the people'.

The result was that, by the end of the nineteenth century, religion and faith in God and eternal verities ceased to be the ruling ideas of modern civilization; the power of religion to influence human thinking and conduct disappeared; man lost the fear of God, and more especially the fear of the devil! Religious dogma had upheld latter more than the former as conducive to moral control of human action and belief. But the scientific spirit shattered faith in the devil and, along with it, faith in God as well. These were treated as primitive superstitions unworthy of modern civilized man. Modern science treated religion as a dangerous error in the beginning and as a harmless illusion in the end.

But the two great world wars, and the various crises– economic and political – that followed the one and preceded the other in this twentieth century, brought about a certain chastening of the spirit of western thinkers, especially of those in the scientifically advanced countries of the West. Social thinkers became less and less cock-sure of their remedies for human ills. Even great scientists began to feel and express that science, as understood and pursued by them, was not enough. Einstein said : 'Science can denature plutonium; but it cannot denature the evil in the heart of man.' That is not its function. Most scientists agree today that science alone cannot ensure human

happiness; it can only create *conditions* for his happiness; but it cannot ensure that man *shall be* happy or man *shall be* really fulfilled. That is not the function of science as understood in the positive sciences of physics, biology, etc.; it is the province of another discipline, the science of the inner nature of man, which is the true meaning of religion as understood in Indian thought.

Religion and Science in the Vedantic Perspective

Modern civilization has overrated science and technology, just as the older civilizations had underrated it. There is need today to view science in its proper perspective–the perspective of total human knowledge and welfare. This is one of the several vital contributions of Swami Vivekananda to modern thought. Dealing with the complementary character of eastern contributions to religion and western contributions to science, he said in his lecture on 'My Master' delivered in New York in 1896 :

'Each of these types has its grandeur, each has its glory. The present adjustment will be the harmonizing, the mingling of these two ideals. To the oriental, the world of spirit is as real as to the occidental is the world of senses. In the spiritual, the oriental finds everything he wants or hopes for; in it he finds all that makes life real to him. To the occidental, he is a dreamer; to the oriental, the occidental is a dreamer playing with ephemeral toys, and he laughs to think that grown-up men and women should make so much of a handful matter which they will have to leave sooner or later. Each calls the other a dreamer. But the oriental ideal is as necessary for the progress of the human race as is the occidental, and I think it is more necessary. Machines never made mankind happy and never will make. He who is trying to make us believe this will claim that happiness is in the machine; but it is always in the mind. That man alone who is the lord of his mind can become happy, and none else. And what, after all, is this power of machinery? Why should a man who can send a current of electricity through a wire be called a very great man and a very intelligent

man? Does not nature do a million times more than that every moment? Why not then fall down and worship nature?'

The Spiritual Urges in Modern Science

The universe was a mystery to man in the primitive stage; it has not ceased to be so for civilized man even in this twentieth century.

If the mystery of the universe has eluded the scientist so much, the mystery of man has eluded him even more.

Man as thinker, man as observer, man as the self has left his 'footprints on the shores of the unknown', on the shores of the 'not-self' aspects of the universe. It is time that science tried to unravel this remarkable mystery of man. There seems to be a profounder mystery hidden within it than in the depths of outer space or of the atom. It is time that science turned its attention to tackling this mystery. All other mysteries pale into insignificance by the side of this one; it holds the key to all other mysteries.

We are that which asks the question. Man is primarily a subject; man cannot be reduced to objective dimensions. He is essentially the seer, the knower, the observer; he is the *drk* or *saksin* or *ksetrajna,* in the language of Vedanta. Here Eddington throws a hint at 'aspects deep in the world of physics, but unattainable by the methods of physics', but containing tremendous philosophical possibilities for advancing man's knowledge of himself and of the universe; this is obviously outside the pale of investigation by the positive sciences and their methods.

'What am I?' Physically, I am a speck of microscopic dust in the vast immensity of the universe. But *through thought I comprehend this universe.* Man as scientist comprehends, in a small formula given by his thought, the vast

phenomena of nature, with its immensity and variety. What must be the profound mystery of man who, in one aspect, is only a pin-point engulfed by the spatial immensity of the universe, but yet, in another aspect, is able to compress the whole of that immensity into a few formulae given by the power and penetration of his thought ?

India's Vision of Universal Science-Religion

Religion as developed and understood in the West was, in its aims and methods and data, opposed to this spirit of rational seeking and investigation. It was taken as something finished and ready-made, which men were asked to believe – a creed or a dogma, a frozen piece of thought, which men were called upon to accept. That was why it came into fierce collision with the advancing tide of science with its spirit of free seeking and rational inquiry. In India, on the other hand, religion has always been understood to be a matter of seeking, finding, and verification, as any of the branches of science. This is a statement that will be found corroborated in the great Upanisads of ancient India and in the literature of Swami Vivekananda of our own times.

Tracing the recurring conflicts of science and religion in the West to the absence of this broad approach, Vivekananda said :

'We all know the theories of the cosmos according to the modern astronomers and physicists, and at the same time we all know how woefully they undermine the theology of Europe ; how these scientific discoveries that are made, act as a bomb thrown at its stronghold ; and we know how theologians have in all times attempted to put down these researches.'

When religion refuses to take the help of reason, it weakens itself Alluding to this in the course of a lecture on 'Reason and Religion,' delivered in England in 1896, Swami Vivekananda said :

The foundations have been all undermined, and the modern man, whatever he may say in public, knows in the privacy of his heart that he can no more "believe." Believing certain things because an organized body of priests tells him to believe, believing because it is written in certain books, believing because his people like him to believe, the modern man knows to be impossible for him. There are, of course, a number of people who seem to acquiesce in the so-called popular faith, but we also know for certain that they do not think. Their idea of belief may be better translated as "not-thinking carelessness."

And, pleading for the application of reason in the field of religion, he continued:

'Is religion to justify itself by the discoveries of reason through which every other science justifies itself? Are the same methods of investigation, which we apply to sciences and knowledge outside, to be applied to the science of religion? In my opinion this must be so, and I am also of opinion that the sooner it is done the better. If a religion is destroyed by such investigations, it was then all the time useless, unworthy superstition; and the sooner it goes the better. I am thoroughly convinced that its destruction would be the best thing that could happen. All that is dross will be taken off, no doubt, but the essential parts of religion will emerge triumphant out of this investigation. Not only will it be made scientific - as scientific, at least, as any of the conclusions of physics or chemistry - but it will have greater strength, because physics or chemistry has no internal mandate to vouch for its truth, which religion has.'

A study of the Upanisads reveals that the subject of religion was approached in ancient India in an objective, dispassionate manner; the aim of the study was to get at truth, and not to hug pleasing fancies and illusions or to idolize tribal passions and prejudices.

In several of his lectures and discourses, Swami Vivekananda has expounded the scientific approach to

religion as upheld in Indian thought. In his lecture on 'Religion and Science', he says :

'Experience is the only source of knowledge. In the world, religion is the only science where there is no surety, because it is not taught as a science of experience. This should not be. There is always, however, a small group of men who teach religion from experience. They are called mystics, and these mystics in every religion speak the same tongue and teach the same truth. This is the real science of religion. As mathematics in every part of the world does not differ, so the mystics do not differ. They are all similarly constituted and similarly situated. Their experience is the same ; and this becomes law....

'Religion deals with the truths of the metaphysical world just as chemistry and the other natural sciences deal with the truths of the physical world. The book one must read to learn chemistry is the book of nature. The book from which to learn religion is your own mind and heart. The sage is often ignorant of physical science because he reads the wrong book – the book within ; and the scientist is too often ignorant of religion, because he too reads the wrong book – the book without.'

Science and Vedanta Complementary

Religion so expounded has a message for all humanity. Science through its technology may build for man a first class house, and equip it with radio, television, and other gadgets; the social security measures of a welfare state may provide him with everything necessary for a happy, fulfilled life in this world, and even, through the state church, in the world beyond ; the man himself may give his house such arresting names as *'Santi Kunja'* (Peace Retreat), or 'Happy Villa'. Yet none of these can ensure that he will live in that house in peace or happiness for that depends, to a large extent, on another source of strength and nourishment, another type of knowledge and discipline – the knowledge and discipline proceeding from religion. If man can have the help of the positive sciences to create a healthy external environ-

ment, and the help of the science of spirituality to create a healthy internal environment, he can hope to achieve total life-fulfilment; not otherwise. This is the view of the Upanisads.

But today, this is not the picture that modern civilization presents. Man in this technological civilization is feeling inwardly impoverished and empty in an environment of wealth, power, and pleasure; he is full of tension and sorrow, doubt and uncertainty, all the time. Juvenile delinquency, drunkenness, suicide, and a variety of other maladies are ever on the increase. Why ? Because man is not inwardly satisfied; he is smitten with ennui and boredom arising from the limitations of his sense-bound *Weltanschauung*. Indian thinkers foresaw this predicament of modern man ages ago. Says the *Svetasvatara Upanisad* (VI. 20) :

Yada carmavad akasam
vestayisyanti manavah :
Tada devam avijnaya
duhkhasyanto bhavisyati

'Men may (through their technical skill) roll up the sky like a piece of leather; still there will be no end of sorrow for them without realizing the luminous One within '

Schopenhauer said a hundred years ago :

'All men who are secure from want and care, now that at last they have thrown off all other burdens, become a burden to themselves.'

Today, man is his own major burden and problem. He can tackle and solve this problem not by going in for more positivistic science, more technology, more life's amenities, more socio-political manipulations of human conditions, but by the cultivation of the science of

religion, by the understanding and practice of this science. Says Swami Vivekananda :

'You must bear in mind that religion does not consist in talk, or doctrines, or books, but in realization ; it is not learning but *being*.'

It is in this sense that India understood religion ; and it is this idea of religion that Swami Vivekananda expounded in the West and the East through his powerful voice. The end and aim of religion, as our ancient teachers put it, is the experience, *anubhava*, of God, through the steady growth in man of his spiritual awareness. *That is the touch-stone of religion.* There is such a thing as the *spiritual growth* of the individual, step by step. We *experience* this growth, just as we see a building rising up step by step, brick by brick. When we live the life of religion, strength comes to us, consciousness becomes enlarged, sympathies grow and widen, and we feel that we are growing into better men, It is only the strength that proceeds from such inward growth and development that will enable man to digest and assimilate the energies released by the progress of science. Such a one alone has the strength and wisdom to convert the chaos of life into a pattern of happiness and general welfare. If religion is taken away from society, what remains is simple barbarism. Ancient civilizations were destroyed by barbarians bred outside those civilizations. But modern civilization, if it is to go the same way, will be destroyed by barbarians bred within the civilization itself. What can save us from this predicament is a little 'Christian love' in our hearts for our neighbours, in the words of Bertrand Russell or a little more altruism, in the words of Pitirim A. Sorokin of Harvard University. This love comes from the *practice* of religion, as defined by Swami Vivekananda and other great teachers of the world. Says Vivekananda :

'Religion is the manifestation of the divinity already in man.'

Again :

'Him I call a *mahatman* (great soul) whose heart bleeds for the poor, otherwise he is a *duratman* (wicked soul).'

That is the function of religion ; the finite man reaches out to the infinite man. No other discipline can give this education to man.

'Now comes the question, can religion really accomplish anything ?', asked Swami Vivekananda, and proceeded to answer :

'It can. It brings to man eternal life. It has made man what he is and will make of this human animal a god. That is what religion can do. Take religion from human society and what will remain ? Nothing but a forest of brutes. Sense-happiness is not the goal of humanity. Wisdom (*jnana*) is the goal of all life. We find that man enjoys his intellect more than an animal enjoys its senses ; and we see that man enjoys his spiritual nature even more than his rational nature. So the highest wisdom must be this spiritual knowledge. With this knowledge will come bliss.'

Conclusion

Understood in this light, there is no conflict between science and religion. Both have the identical aim of helping man to grow in spirituality, of ushering in a better social order which alone can provide him with the stimulus to total life-fulfilment. Each by itself is insufficient and helpless. They have been tried separately with unsatisfactory results. The old civilizations took guidance solely from religion ; their achievements were partial and limited. Modern civilization relies solely on science ; its achievements also have turned out to be partial and limited. The combination today of the spiritual energies of these two complementary disciplines in the life of man will produce fully integrated human beings and thus help to evolve a complete human civilization for which the world is ripe and waiting. This is

the most outstanding contribution of Swami Vivekananda to human thought today. This synthetic vision of his finds lucid expression in a brief but comprehensive testament of his Vedantic conviction.

Each soul is potentially divine.

The goal is to manifest this divine within by controlling nature, external and internal.

Do this either by work, or worship, or psychic control, or philosophy - by one, or more, or all of these - and *be free*.

This is the whole of religion. Doctrines, or dogmas, or rituals, or books, or temples, or forms, are but secondary details.'

The Vedanta expounded by Vivekananda as the synthesis of science and religion is also the synthesis of head and heart, of the classical and the romantic in the human heritage. The erstwhile tendency in modern education to treat the humanities and the sciences as mutually exclusive disciplines is giving place to the Vedantic awareness that they are complementary to each other. Himself 'the personification of the harmony of all human energy', in the words of Romain Rolland, Vivekananda has bequeathed to man, in a moving passage, his vision of the unity and synthesis of all human energy and aspiration. Making a prophetic reference to the future religion of humanity in the course of his lecture on 'The Absolute and Manifestation' delivered in London in 1896, he said :

'In Buddha, we had the great universal heart and infinite patience, making religion practical, and bringing it to everyone's door. In Sankaracharya, we saw tremendous intellectual power, throwing the scorching light of reason upon everything. We want today that bright sun of intellectuality joined with the heart of Buddha, the wonderful, infinite heart of love and mercy. This union will give us the highest philosophy. Science and religion will meet and shake hands. Poetry and philosophy will become friends. This will be the religion of the future, and if we can work it out, we may be sure that it will be for all times and peoples.'

Science and the Problems of Development

INDIRA GANDHI

Asia today means disinherited millions of people, whether they live in the desert, the jungle or the crowded deltas. But Asia did not always suggest want and penury. It is the home of many civilizations and all the great religions. Could these civilizations have grown if they had not been held together by adequate technological mastery?

The early Indians, the early Chinese, the Arabs, to name only a few of the great people of this continent, made notable discoveries in medicine and mathematics, in astronomy and architecture, in metallurgy and agronomy. In my own country, a great surgeon who lived 2,200 years ago is said to have used 500 different instruments and accomplished miracles in plastic surgery. On the periphery of New Delhi you can see an iron pillar which has defied the elements for fifteen hundred years and still stands without rust or blemish.

Asia had its fair share of scientific discoveries. But a time came when its people, weighed down by the opule-

nce of their rulers, lost the art of innovation and self-renewal. They fell prey to more vigorous and dynamic societies which possessed newer technologies. It is no wonder that the Industrial Revolution created new empires.

With the passage of time, the innovation cycle began to grow shorter. At first any new invention might hold the field for several centuries, then perhaps no more than a century, then only a few decades. The Industrial Revolution gave this innovative process a completely new thrust. The pace of change quickened. In contemporary technology, obsolescence is seldom far behind invention.

Technology represents the end application of science. It calls for a certain social climate and economic potential for speedy and widespread application. Modern science and technology often require large investments, especially in highly trained personnel in numerous categories all along the innovation chain.

Asia has regained its freedom. But the gap in technology remains. In some ways, the extraordinary proliferation in new technology has even widened it. This is one of the sharpest causes of tension in the world, creating situations which are explosive and exploitable.

The developing countries might be backward in science but they have one advantage. They can sometimes telescope centuries into a few years, take advantage of the experience of others and perhaps even alter the sequence of change. People know about penicillin in our remote villages, and aeroplanes have penetrated some parts of India which did not know motor vehicles, bullock carts or even wheel barrows!

How does change come about? Often enough it is brought about not only by individual entrepreneurs but by the initiative of determined groups, or by whole nations. Japan provides an example of the social transformation induced by a ruler and his advisers. In India and a few other countries, the powerful nationalist movements were deeply imbued with the urge for social and economic change.

Asia is at several stages of economic development, with Japan presenting a spectacle of modern amenities expanding far and wide. Elsewhere there are villages, some in my country, which do not look very different from what they were in the time of the Buddha. Their timelessness attracts refugees from the advanced nations, for progress, as it has evolved in the advanced countries, has so separated man from nature that he is not at peace either with his environment or with himself.

There are many theories on the induction and forward movement of economic development and technological change. Amidst a host of others, I should like to indicate some factors which play an important part in this process.

First, science itself. We are apt to think of it merely as an aid – a means of helping industry or of bringing greater comfort in our lives. But science does not merely better the old. Often enough it upsets the old. It creates something that is new to the world and to human consciousness.

Then there is education, not just for a favoured few but for the masses – unfolding knowledge, opening up new worlds and arousing new desires. But much of today's frustration and restlessness is because our educational

systems are too narrow and inflexible to promote the spirit of understanding and tolerance and the vision which is essential to meet the challenges of our changing world.

Visible benefit makes the most immediate impact. When individuals or groups are convinced that the adoption of modern science and technology will increase their income or strengh, they jettison old beliefs for new ideas and methods. The Indian farmer has often been accused of resisting change. This charge is somewhat unjust. Did he not in the last century take to growing crops which were strange to our country, such as tobacco and ground-nuts?

The cultivation of these imported crops was taken up even by small farmers because it meant more and readier money. A similar change is again taking place with the intoduction of high-yielding crop varieties. So, while tradition and superstition do block progress, we should not underrate the strong pull of modernity and of self-interest.

Another important factor is the motivation and endeavour of governments. Ambition is the spur. But the experience in Asia is that unless governments themselves are committed to economic growth, such growth is slow to come.

The hundred years before we won our independence provide an example of how slow such growth can be. Our first railways and textile mills were opened in the 1850s. Yet until the late 1940s we did not make any locomotives in our country and hardly any textile machinery. What was lacking was governmental will, for the government was alien and indifferent. Over the same period, Japan came to the forefront of technology because it had its own government, one that was committed to

technological change. National temperaments might have played some role, but history has many instances where nations have undergone changes of personality under the influence of determined leadership.

The role of the State in bringing about change is well understood in Asia. Hence national planning has been adopted by many countries, whatever their political theory.

It is obvious that there can be no economic development without technological change. The life-work of my father, Jawaharlal Nehru, was to free India from all the shackles which prevented her full flowering – whether they were political, economic or the dead weight of outmoded thought. He once said : 'What is planning if not the application of science to our problems ?'

In India we have all the problems of the developing countries and some of our own. Our size magnifies every problem and every programme. If a pilot experiment in agriculture succeeds, at once there is a clamour to apply it at 550,000 villages. Planning on this scale in a completely democratic set-up and in conditions where each decision is publicly debated and accepted, adds complications.

With all our progress, we still can claim only a partial transformation of our society. We have today 300,000 engineers, a more than fivefold increase since independence. Our machine-tool output has risen one hundred times. We are now exporters of locomotives, of steel products, of electronic instruments and of radioisotopes for medicine.

We still live in many layers, in many ages. Indeed, the early stages of development have accentuated disparities. It is only through perseverance and the steady

application of science that these disparities can be bridged and the backward areas enabled to catch up with the more advanced ones.

We have regarded science as the means to higher production, to self-reliance, as well as to the reduction of disparities within society. In our view, the country cannot break out of backwardness only by establishing basic and consumer industries, but by applying modern technology to agriculture.

We have given every encouragement to agricultural research and to the extension of research to the field. We have assigned a high priority to irrigation – large dams as well as small tube-wells – so as to free the farmer from entire dependence on the rains. We have promoted rural electrification. Much of this power is used for agriculture. We have developed a nation-wide organization to distribute fertilizer and credit pumps and tube-wells.

The intensive use of fertilizer and the adoption of the new high-yielding varieties which have been developed by our scientists have just given us the biggest harvest in our history. After two years of terrible drought we are heartened at this breakthrough. Indeed, the drought itself spurred our efforts to apply science and technology to agriculture, which is the livelihood of seven Indians out of ten. We are determined to stabilize the gains we have made.

Medical science has enabled us to virtually eradicate malaria, to bring down the birth-rate and to increase longevity. The resultant population growth now attracts the highest priority and this constitutes a key area of Indian medical research and application. And so on down the list.

Ten years ago, our government adopted a scientific policy resolution which stressed the importance of scientific training and research. It also declared : 'Science has led to a growth and diffusion of culture to an extent never possible before.... It has provided new tools of thought and has given to civilization a new vitality and a new dynamism....' The resolution pointed out that science and technology can make up for deficiencies in natural resources and reduce demands on capital.

In working out this policy we have encountered several problems. We train young and able scientists. But it is natural that the advanced countries should provide more and better opportunities for work and satisfaction. It seems that our investment serves as technical aid in reverse – from a developing country to an advanced country!

There is also a debate regarding foreign technology versus indigenous technology. Science may not know national barriers but patent laws do. Along with foreign aid we receive foreign technology. When we do something for the first time, the import of technological know-how becomes inescapable. Yet many aid agreements are such that we are compelled to buy machinery abroad even when we can make it in India, and to accept foreign technicians when they do exist in India. The time factor and the need to avoid risks force these package deals upon us.

We are conscious that growth cannot be sustained on borrowed or even adapted technology. True self-reliance can come only as we develop the ability to solve our technological problems. Some are small but on a big scale. How can our villages develop unless a wide range of tools

can be placed at their disposal and modern fuel brought to them at nominal prices? We often hear the term 'intermediate technology.' In this our scientists and technologists have much to do.

General and technical education has expanded considerably over the past twenty years in India and we have developed a significant scientific and technological capability in several directions. It is now our endeavour to rationalize the structure of Indian science and to relate it more closely with the processes of planning and development. We must have a 'policy for science' and equally 'science in policy.'

The countries of Asia have much to learn from one another and much to share. India invites such co-operation in a spirit of partnership and friendship. Interdependence can be meaningful and mutually beneficial only if it arises out of independence.

Science – in other words, 'knowledge – is not the enemy of religion; for, if so, then religion would mean ignorance.

O. W. Holmes

Research has been described as the mother of industry and while some of the older and more traditional industries may have originated without the aid of science, it cannot be denied that all industries today depend upon science and research not only for their progress and improvement but also for their survival.

H. A. L. Fischer

Research, Industry and Society

Y. NAYUDAMMA

Modern life is the offspring of science and technology and it is now patent that we cannot progress without science and technology.

For research to flourish, the industry and society must provide the necessary environment. Knowledge can be power only when there are able people to use it. As I understand it, the public criticism is not that scientists are second rate ; not that there is not enough output of research and technology, but that science and technology has not been effectively utilised to benefit the industry and the country. The question really then is effective utilisation of research.

This raises the questions like, what is research ? What are the conditions for success of research ? What makes research tick ?

Let us then begin with, what is science and technology ? Crudely, science can be defined as knowledge and technology as the practical use of that knowledge. Technology very simply put is doing something about it.

What is research ? Research is a high hat word that is much used and abused. Essentially it is nothing but a state of mind – a friendly welcoming attitude towards change. Going out to look for a change, instead of waiting for it to come. For practical men, it is an effort to do things better. Research is really a 'Tomorrow mind' instead of 'Yesterday mind'. In research, we find trials and joys, satisfactions and disappointments, gloom and humour – a blend of sublime and ridicule. Research and accumulation of knowledge is like pouring water slowly on a dusty floor. Like water, it continually spreads– unexplored islands are left behind–but these are eventually closed up.

There is a tendency to classify research into fundamental and applied - knowledge for knowledge sake and knowledge for practical use. But, it is good to remember what is fundamental research today is applied tomorrow! I would think that the distinction between good and bad research is more meaningful and useful. Goal - orientated or motivated - research is actually indivisible and more successful. Many insist on need-oriented research as the best way to insure utilisation. But it is good to remember production of materials like nylon, polythene, penicillin, transistor, etc., did not come into being because it was a recognised need. The need came after the development of the product. We should therefore direct our research towards not only identified needs but also should be alert to the opportunity of creating newer demands and shape the future.

From the society's point of view, research is useless in a practical sense unless it is exploited. Such exploitation however requires some successful, aggressive, forward looking satisfactorily organised mechanism for develop-

ment, trial, production, distribution, evaluation and improvement.

From science to sales, or the utilisation of research results occurs in three overlapping steps. Invention, Innovation and Technical Transfer.

The first step is invention, the conception of a notion, a vision, a potential possibility to be married to a potential need. The second step, innovation involves a high degree of spirit of adventure, risk and entrepreneurship to make it work ; finally the technology so developed should be transferred to the industry. This technology transfer is the process of matching solutions in the form of existing science and technology to the problems in commerce and business.

What then are the conditions for success of science and technology in service of society ?

1. First and foremost, we must have scientists and technologists. One can import technology, but cannot import scientists to act as nuclei of research. No country can prosper simply by the importation of research results. Every country must do research on its own natural resources and raw materials ; it must form and maintain its own scientific personnel and it must develop its own scientific community.

2. The second important factor is the institution which supplies research results. The task of the research institute comprises the proper identification and selection of problems and allocation of priorities relevant to country's economic growth. No less important is the efficient conduct of research which includes a following a project where it leads, and bringing it to conclusion. The knowledge when to close the project is equally impor-

tant. Constant attention should be paid to the way in which the expected results can be made technologically and economically practicable. The results and their applicability must be intelligently and persuasively conveyed to the prospective user in an assimilable form. It is not enough to conduct research ; it is necessary to sell it. Thus the planning, organization and management of research in the institute and its development and sale are important for successful utilisation of research. The capacity to succeed will also depend upon the strategy and the value of management more than its research potential.

3. The third factor is the potential user. It is the potential user's capacity to appreciate and actually utilise the relevant technology made available by research that is decisive. Any communication line has to have a sender and receiver. These two have to be talking in the same language and have to be on the same circuit. Research result can be sold only within a pre-existing matrix of continuous and intimate interaction or dialogue between researcher and industrialist. The two must live in common culture in which each can imagine himself in the role of the other.

4. Even when a nation has scientific and technological development, it can still produce poor economic results without a proper market and enterprise. Creation of markets, identification of needs and demands and economic environment are thus important. Applied research is most effective when it is coupled to a market that provides an automatic measure of effectiveness. Applied research is most effective when it is conducted within and by the industry itself.

5. It cannot be said that science will flourish in the absence of strong Government action. Fortunately for India, the Government is highly sympathetic to science and technology. The nation has now a firm commitment to science and a strong will to achieve results through the application of science and technology. The nation is clearly defining the goals and objectives which would meet the needs of the country. These needs are being reduced into a series of researchable relevant components and allotted to research institutes. This process should be subjected to a continual review as new results emerge.

6. Last but not the least, the major prerequisite for science to succeed is a public opinion sufficiently well-informed and enlightened to give every support to scientists. A technology transfer programme should include special efforts to increase the technical literacy in business and entire society that constitutes to the demand and understanding of technical change. Well-informed public opinion can be got only through education. In this fast changing world of science, we need to focus our emphasis on education on broad background of meaningful and interrelated knowledge, well-established generalised habits and attitudes towards creativity, scientific method, critical thinking, devotion to sense of values and ideals and individual excellence. Superstition, ritual and prejudice must give way to rational thinking, questioning attitude, spirit of adventure and scientific temper.

7. It will thus be seen, the research yield will largely be dependent upon the proper identification and definition of problems, problems chosen relevant to economic growth, priorities for national projects, proper orientation of technology to the felt needs, to raw material resources and the

genius of the land, efficient conduct of research; proper facilities for designing, engineering and scaling up, involvement and firm commitment of the industry, society and government, necessary atmosphere and economic environment for research to grow. The research yields differ also from country to country, differing in levels of incomes, levels of technology, in industrial structure, size, technical and skilled manpower, ratios of indigenous to modern technology and the rate of expenditure on research and development. Thus, it is not fair to compare the work of researchers of one country to the other.

8. It is science and technology and the efficient use of it that is critical in the economic growth of the country. It is also clear that research and industry are partners to promote and catalyse the progress of the country. The support for science and technology from the society should be an act of faith. The society is expecting if not demanding a continuous rising standard of living through science and technology without apparently sufficiently understanding the conditions conducive to research and without creating proper economic environment for effective utilisation of research. While the scientists and technologists have an important part to play by focussing their research to achieve the felt needs of the country, the society in turn shall have to change some of the traditions, attitudes, resources, forms of outmoded organisations, etc., that have been inherited.

9. We, in our country, have long been used to Bharatanatyam – a single pretty girl dancing and several others enjoying. Research and industry on the other hand are like two partners in a ballroom dance, one leading the other in step with the tune – not only do both

enjoy the dance, it is a pleasure for others to watch, So is the case with the community, society and the country progressing through the interaction and impact of research and industry.

10. It has become clear that the process whereby research and industry are integrated involves far more than industry's approaching research and asking for a solution to a clearly formulated problem which has occurred to it. It is equally much more than a researcher's discovering a process which it recommends to industry and which industry then adopts to its own advantage.

The presupposition in the effective collaboration of industry and research is the creation of a common culture. As it stands, research and industry in India are running parallel like the two banks of a river, so near and yet so far. What is most needed is the creation of common industry-research culture. The researcher and industrialist must each live in both the worlds in such a manner that the worlds of research and industry become a single world.

11. To the research and industry, one may add the third dimension, that is the society. The society should create a proper social and economic environment and the support for science and technology from the society should be an act of faith. Thus, it is obvious that research, industry and society become an equilateral triangle.

12. I would now like you to ponder whether each one of us whether be in research, industry or society is contributing our share and whether we are all working closely and collectively ! It is an inherent obligation for every one of us to participate fully in the march of science which is mankind's greatest enterprise today !

Science does not simply sit down and pray for things to happen, but seeks to find out why things happen. My preferences are all for science and the methods of science, for science has opened up tremendous new vistas which wait to be explored.

Science and the scientific spirit and method are the basis of life today. There lies in science the search for truth on the one hand, and the betterment of humanity on the other.

Science to-day has perhaps begun to cross the borders of morals and ethics. If it gets divorced completely from the realm of morality and ethics, then the power it possesses may be used for evil purposes. If it ties itself to the gospel of hatred and violence, undoubtedly it will have taken a wrong direction which will bring much peril to the world.

It is therefore with the temper and approach of science, allied to philosophy, and with reverence for all that lies beyond, that we must face life. Thus we may develop an integral vision of life which embraces in its wide scope the past and the present, with all their heights and depths, and look with serenity towards the future.

Jawaharlal Nehru